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COMPUTER SCIENCE SECTION

ORIGINAL

SUMMARY
OF
AWARDS

FISCAL YEAR 1980

COMPLETED

NATIONAL SCIENCE FOUNDATION
Directorate for
Mathematical and Physical Sciences
Division of
Mathematical and Computer Sciences
Computer Science Section
Washington, D.C. 20550

PREFACE

The purpose of this report is to provide the scientific community with a summary of those grants awarded by the Computer Science Section of the Division of Mathematical and Computer Sciences in fiscal year 1980. The report lists fewer than the actual number of projects currently receiving support because the duration of some grants exceeds one year.

Similar areas of research are grouped together for reader convenience. The reader is cautioned, however, not to assume these categories represent either the totality of interests of each program or the total scope of each grant. Projects may bridge several programs or deal with topics not explicitly mentioned herein. Thus, these categories have been assigned administratively and for the purposes of this report only.*

In this document, grantee institutions and principal investigators are identified first. Award identification numbers, award amounts, and award durations are enumerated after the individual project titles. Within each category, awards are listed alphabetically by institution.

Readers wishing further information on any particular project described in this report are advised to contact principal investigators directly.

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* To get an idea of the scope of possible programs, consult What Can Be Automated? The Computer Science and Engineering Research Study (COSERS), Bruce Arden (Ed.), MIT Press, Cambridge, MA (1980).

CONTENTS

Page
Preface.. i
Table of Contents.. ii
Introduction... iii
Summary.. vi

Computational Mathematics.................................. 1

Theoretical Computer Science............................... 7
  Concrete Complexity; Analysis of Algorithms........... 7
  Parallel and Distributed System Models................ 17
  Abstract Complexity; The Logic of Programs............ 20
  Theory of Databases................................... 26
  Automata and Language-based Models; Fuzzy Sets........ 27

Software Systems Science................................... 33
  Programming Languages and Compilers................... 33
  Operating Systems..................................... 38
  Data Base Systems..................................... 40
  Formal Structure of Programs.......................... 41
  Concurrency... 44
  Verification.. 46

Computer Systems Design.................................... 47
  Computer System Architecture.......................... 47
  Fault Tolerance and Reliability....................... 55
  Computer System Performance Measurement and Evaluation 56
  Computer Graphics..................................... 59

Software Engineering....................................... 63
  Quality Software...................................... 63
  Symbolic and Algebraic Manipulation................... 68
  Software Studies and Metrics.......................... 70
  Program Testing and Verification...................... 73
  Software Tools and Programming Environments........... 75

Intelligent Systems.. 80
  Theories of Pattern Analysis, Synthesis,
    and Recognition by Computer......................... 80
  Mechanization of Perception and Language.............. 83
  Mechanization of Knowledge and Inference.............. 91

Special Projects... 98
  Database Research..................................... 98
  Privacy & Security.................................... 102
  The Societal Impact of Computing...................... 104
  Modelling & Simulation................................ 107
  Other Projects, Symposia, Colloquia, and Studies...... 109

Computer Science Research Equipment........................ 111

Experimental Computer Science.............................. 117

INTRODUCTION

This report provides summaries of awards made by the National Science Foundation (NSF) through the Computer Science Section in Fiscal Year 1980.

In Fiscal Year 1980, Computer Science Section award activities were carried out through six programs. Topics of interest to the Foundation include, but are not limited, to the following:

Theoretical Computer Science

Theories of computation and formal languages; analysis of algorithms; theoretical models for computation; and other theoretical models for computation; and other theoretical problems concerned with the foundations of computer science.

Software Systems Science

Conceptual basis for the specification of future software systems and the necessary experimentation with such systems, including: advanced programming languages and optimizing compilers: functional and relational specification program transforming systems; systems for the verification and proof of correctness of programs; the study of the concurrency of operations; the discovery of new algorithms and improved measures of effectiveness of known algorithms.

Computer Systems Design

Principals of computer systems design relating to the structure of computer systems or the process of systems design. Topics include, but are not limited to: computer system architecture; distributed computer systems; integrated hardware/software systems; performance measurement and evaluation; fault tolerant systems; logic design; computer graphics; man-machine interaction: and VLSI design methodology. The scope of this program includes experimental implementation where that is an integral part of the research.

Software Engineering

The structure and design process of computer software, especially verification, testing, portability, reliability, and human interfacing to numeric and non-numeric softrware systems. Areas of emphasis include: program validation and testing; software tools; and human factors in software design and use. The program also supports research in computationally oriented numerical analysis, the design and construction of high quality portable software for scientific research, and experimental implementation where that is an integral part of the research.

Intelligent Systems

Computer-based systems that have some of the characteristics intelligence. Relevant areas include: pattern recognition; pattern generation; knowledge representation; problem solving; natural language understanding; theorem proving; and areas related to the automatic analysis and handling of complex tasks.

Special Projects

General and specialized projects in experimental computer science; computer science research equipment; societal issues in computer science including privacy and security; legal aspects of computing; and social and economic impact; new directions in computer science and applications including computer networks, database management; computer-based modeling; and other topics of special interest in computer science.

Additional Information

For additional information on any of the projects, contact the Principal Investigators directly.

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November 1980

SUMMARY

	Number of Projects	Value of* Awards
Computational Mathematics	17	$756,454
Theoretical Computer Science		
Concrete Complexity; Analysis of Algorithms	30	$943,828
Parallel and Distributed System Models	9	$386,537
Abstract Complexity; The Logic of Programs	17	$620,346
Theory of Databases	3	$124,473
Automata and Language-based Models; Fuzzy Sets	14	$500,312
Software Systems Science		
Programming Languages and Compilers	11	$871,770
Operating Systems	7	$284,997
Data Base Systems	2	$100,455
Formal Structure of Programs	8	$706,857
Concurrency	3	$233,948
Verification	1	$148,536
Computer Systems Design		
Computer System Architecture	20	$1,518,248
Fault Tolerance and Reliability	2	$78,853
Computer System Performance Measurement and Evaluation	5	$388,216
Computer Graphics	7	$656,898
Software Engineering		
Quality Software	12	$508,921
Symbolic and Algebraic Manipulation	4	$299,170
Software Studies and Metrics	7	$398,384
Program Testing and Verification	3	$193,070
Software Tools and Programming Environments	12	$854,873
Intelligent Systems		
Theories of Pattern Analysis, Synthesis, and Recognition by Computer	10	$519,492
Mechanization of Perception and Language	18	$1,106,207
Mechanization of Knowledge and Inference	20	$1,119,497
Special Projects		
Database Research	9	$649,589
Privacy & Security	4	$119,647
The Societal Impact of Computing	7	$698,298
Modelling & Simulation	3	$330,526
Other Projects, Symposia, Colloquia, and Studies	4	$216,166
Computer Science Research Equipment	18	$1,968,157
Experimental Computer Science	2	$868,846

* Fiscal Year 1980 funds only.

COMPUTATIONAL MATHEMATICS

University of Arizona; David F. Shanno; **Numerical Methods for Nonlinear Optimization With Many Variables**; (MCS-7922914); $59,365; 24 mos.

This research is concerned with the minimization of nonlinear functions of many variables, both unconstrained and subject to linear constraints. For unconstrained problems with sparse Hessian matrices research will be conducted to generate algorithms analogues to variable-metric algorithms for non-sparse cases. The research will concentrate on stable globally convergent algorithms. Recent improvements in conjugate gradient algorithms will be investigated to obtain maximally efficient algorithms.

Stanford University; Gene H. Golub and Joseph Oliger; **Numerical Linear Algebra**; (MCS-7811985A01); $71,797; 12 mos.

This research involves investigations into a number of areas in numerical linear algebra. These include the generalized algebraic eigenvalue problem, updating techniques for matrix factorization, the inverse eigenvalue problem and solutions of sparse systems of linear equations. During all of these studies there will be an emphasis on the development of high quality numerical algorithms which take advantage of recent developments in computer technology.

Univ. of Southern California; Wlodek Proskurowski; **Fast Numerical Methods For Solving The Helmoltz Equation And Related Problems**; (MCS-8003382); $17,960; 24 mos.

This project involves research on efficient numerical methods for solving the Helmholtz equation in arbitrary bounded planar region, discretized by finite difference and finite element methods. Capacitance matrix techniques provide the tool with which this goal can be achieved. Development of mathematical software for general use, progress in the new methods based on variational principle, and upgrading the performance of the existing codes using the new approach will be considered. Extension of the method to more complicated problems, like the time dependent problem and the biharmonic equiation, are taken into account.

Colorado State University; Stephen F. McCormick and Gerald D. Taylor; **A Numerical Investigation of Surface Fitting and Mesh Refinement Techniques**; (MCS-8017056); $44,685; 12 mos.

This project is involved in the development and analysis of various iterative methods for solving problems in nonlinear two-point and partial differential boundary values and integral equations (and associated eigenproblems), surface fitting, and algebraic eigenproblems. Investigation will continue into these areas by extending the analysis and numerical experiments, including comparisons with competitive techniques in each area. Special emphasis will be placed upon mesh refinement and surface fitting techniques for very large data sets. A new project area, namely, theoretical analysis of multigrid methods, will also provide a focus of attention.

Colorado State University; P. M. Prenter; **Numerical Iterative and Noniterative Filters for Ill-Posed and Noisy Equations Arising From Linear and Nonlinear Inversion Problems**; (MCS-8007956); $23,552; 12 mos.

This project involves research and development of both iterative and noniterative filters for the numerical solution of ill-posed and noisy linear and nonlinear inversion problems. Special emphasis will be placed on a truncated continued fraction approach to the construction of logistic low pass filters, on a generalized linear and nonlinear filtering analysis of Abel-Volterra first-kind integral equations in the time series domain, on the extension of weak finite element regularatory schemes for first-kind integral equations to singular kernels via generalized product integration schemes, and on a sharpening of recent error estimates for regularatory filtering of ill-posed operator equations.

Northwestern University; Erwin H. Bareiss; **Probabilistic Error Analysis for Constant Relative Difference and Floating Point Computers**; (MCS-7920150); $50,963; 24 mos (Joint support with the Computer Systems Design Program - Total Grant $85,963).

The research involves an investigation into the probability distributions of roundoff errors in the four basic arithmetic operations of addition, subtraction, multiplication, and division. These error distributions will be studied for various techniques of representing numbers in a computer including fixed point, floating point and constant relative difference number representations. Application of these distributions to the error analysis of numerical algorithms will also be investigated.

Purdue University; Walter Gautschi; **Gauss Type Quadrature Rules**; (MCS-7927158); $29,171; 24 mos (Joint support with the Applied Mathematics Program - Total Grant $39,171).

The numerical solution of boundary value problems, singular integral equations, conformal mapping problems, and multiple integration problems often calls for the evaluation of one-dimensional integrals that involve a weight function. Effective tools for computing such integrals are the quadrature rules of Gauss, Radau, and Lobatto type. The object of this study is to develop constructive methods for generating these quadrature rules and to provide appropriate mathematical software. It is expected that the results of this research will stimulate the employment of these advanced integration schemes in applications such as those mentioned above.

Massachusetts Institute of Tech.; Virginia Klema; **Summer Research Conferences in Numerical and Statistical Analysis to be Held at the University of Delaware, June 15-27, 1980**; (MCS-7903876A01 & A02); $15,000; 12 mos (Joint support with the Special Projects - Mathematics Program, and an Interagency Transfer - Total Grant $43,000).

To satisfy a number of needs for interdisciplinary research and training in numerical analysis, data analysis and mathematical statistics, a series of intensive summer conferences will be held each summer for a period of at least five years. Starting with 1980, the two-week conference will bring together well-established research workers from statistics and numerical analysis, along with a group of about fifty participants from these fields and other disciplines which make substantial use of numerical analysis and statistics.

In addition to presenting numerical and statistical techniques in an integrated framework, increasing the detailed understanding that established researchers in each field have of the concerns and problems of the other, and promoting joint research on problems of mutual interest, the anticipated benefits from these conferences include monographs based on conference lectures, earlier appearance of textbooks combining modern numerical and statistical techniques, and wider introduction of courses in this interdisciplinary area at both the graduate and undergraduate levels.

Mass. Institute of Tech.; Jeremy F. Shapiro; **Experimental and Theoretical Investigations into Integer Programming and Dual Methods**; (MCS-7724654A02); $57,693; 12 mos.

This research concerns experimental and theoretical questions in integer programming. Particular emphasis will be placed on developing and extending a complete duality theory for pure integer programming and the implementation of two experimental computer codes using this theory in a branch and bound framework to solve integer and imxed-integer programming problems. Experimental and related theoretical studies on families of integer and linear programming problems will be performed with an aim towards better understanding and improvement of the resulting procedures.

Cornell University; Charles Van Loan; **Applied Matrix Computations**; (MCS-8004106); $35,000; 24 mos.

The aim of this research is to adapt and extend some of the well-known algorithms in the matrix computation field to selected problems in control theory and statistics. These problems include (1) the algebraic Riccati equation, (2) the observability and controllability of linear systems, and (3) least squares fitting when errors are present in both the observations and the data. The algorithms to be developed will rely on orthogonal matrices and two benefits of the research are expected as a result: the development of reliable software and the construction of informative perturbation theories.

CUNY City College; Donald Goldfarb; **The Use of Negative Curvature in Minimization Algorithms**; (MCS-8006065); $76,986; 24 mos.

This study is an investigation into how to best use negative curvature when minimizing nonlinear functions. The emphasis will be on the development of efficient and robust algorithms and reliable software, and both unconstrained and constrained problems will be considered. This intends to analyze and implement a curvilinear path steplength algorithm recently developed by the investigator and versions of the generalized Goldfeld-Quandt-Trotter and transformed gradient path algorithms which use the stable Bunch-Parlett factorization of symmetric indefinite matrices. Both modified Newton and quasi-Newton type approaches will be investigated. A collection of non-convex minimization problems will be assembled and used for testing the algorithms and codes that are developed.

New York University; Olof Widlund; **Fast Methods for the Solution of Large Finite Difference and Finite Element Systems of Equations**; (MCS-7902882A01); $38,000; 12 mos.

This research involves work on efficient methods for solving highly structured finite difference and finite element systems of equations. The goals of the research are threefold, to provide an improved mathematical framework, fast and reliable numerical methods and a convenient FORTRAN Program for the solution of finite element approximation to large systems of difference and differential equations.

University of Pittsburgh;- Werner C. Rheinboldt; **Computational Continuation Processes for the Solution of Nonlinear Systems of Equations**; (MCS-7805299A02); $43,778; 12 mos.

This research program concerns the development and analysis of adaptive computational continuation algorithms considered, in a broad sense, as the collection of all methods necessary for a computational analysis of specified parts of the solution field of equations of the form F = b where $f : R^m \longrightarrow R^n$ is a given mapping and $m > n$. Some of the topics to be addressed are the detailed analysis of classes of predictor-continuation methods and the design of efficient step controls for them; investigation of the use of incremental formulations to compute or approximate the derivative of F; studies of numerical methods for bifurcation problems; design and anlysis of adaptive parameter change algorithms, and their incorporation into the continuation processes; investigation of the influence of input changes upon the location of the limit points; general stability studies of the problems and methods considered; and last but not least the development of complete prototype programs for the analysis of solution fields and their use in an experimental assessment of the merits of the various methods and approaches.

University of Texas at Austin; David Young and David Kincaid; **Research and Development of Iterative Algorithms and Software for Elliptic Partial Differential Equations**; (MCS-7919829); $50,673; 12 mos (Joint support with the Applied Mathematics Program - Total Grant $67,673).

This project involves research and development of iterative algorithms and software for solving large systems of linear algebraic equations with sparse matrices. Particular emphasis will be placed on linear systems arising from the numerical solution of elliptic partial differential equations.

The work will have two aspects, namely, development of research-oriented software and research on iterative algorithms. The first aspect of the work will involve a substantial expansion of the capability of the ITPACK package to include more powerful iterative algorithms and to allow for handling more general classes of linear systems including systems with nonsymmetric matrices. It will also involve continued participation in the ELLPACK project. The second aspect of the work is closely related to the first and involves research on iterative algorithms with emphasis on effective methods for solving nonsymmetric linear systems.

University of Virginia; Lois Mansfield; **Research on Finite Element Methods**; (MCS-8016532); $33,180; 12 mos.

This project will study finite element methods for the numerical solution of partial differential equations arising primarily from nonlinear problems in solid mechanics. In particular, the large deformation analysis and the buckling of shells and plates are an important aspect of the analysis of structures. The finite element method is being used to provide numerical solutions to these problems. The research in this area is still in the beginning stages and there are many open problems, both in the formulation and mathematical analysis of the methods and in the solution of the resulting nonlinear algebraic equations.

Univ. of Wisconsin-Madison; C. W. Cryer; **Free Boundary Problems**; (MCS-7726732A01); $56,395; 24 mos.

Free boundary problems are boundary value problems in which part of the boundary is unknown and must be determined as part of the solution. Examples include: (1) elastic/plastic problems in mechanics (the free boundary is the elastic/plastic interface); (2) confinement by magnetic fields of plasmas in fusion reactors (the free boundary is the plasma/vacuum interface); and (3) transonic flow past an airfoil (the free boundary is the subsonic/supersonic interface).

This research involves the study of both mathematical and numerical aspects of free boundary problems, and includes the following: (1) The solution of large linear complementarity problems (one of the many ways in which free boundary problems can be formulated) using parallel processors; (2) The analysis of certain axisymmetric free boundary problems (such as the elastic/plastic torsion of shafts); (3) The numerical solution of Milne-Thomson integral equations (another method of reformulating some free boundary problems).

University of Wisconsin, Madison; Olvi L. Mangasarian, R. R. Meyer, and S. M. Robinson; **Computation and Theory in Nonlinear Programming**; (MCS-7901066A01); $85,436; 12 mos.

The investigators will conduct research in several areas of mathematical programming. The areas to be investigated include piecewise-linear problems, large scale optimization, and general nonlinear programs. They will research both general theory and algorithmic techniques in these areas. Computational testing of the algorithms developed will be carried out on realistic problems in such areas as free boundary problems and pipeline network analysis.

THEORETICAL COMPUTER SCIENCE

CONCRETE COMPLEXITY: ANALYSIS OF ALGORITHMS

University of Arizona; Peter J Downey; **Stochastic Scheduling: Algorithms and Complexity**; (MCS-8004679); $15,906; 24 mos (Joint support with the Software Systems Science Program - Total Grant $31,812).

The overall goal of this research is to develop mathematical models for the allocation of resources in computer systems, especially models in which job resource requirements are known only probabilistically. Given these models, the investigators are interested in developing efficient scheduling and resource allocation policies which are optimal or near-optimal with respect to some desirable performance measure.

This investigation will be carried on jointly by both Dr. John Bruno of the University of California-Santa Barbara and Dr. Peter Downey of the University of Arizona.

Stanford University; Robert E Tarjan; **Efficient Combinatorial Algorithms and Their Applications**; (MCS-7826858A01); $30,616; 12 mos.

This project pertains to the study of combinatorial algorithms. The objectives of the research are:

1. to develop and classify general methods for solving combinatorrial problems;
2. to apply the general methods to the solution of specific practical combinatorial problems, using various approaches if possible;
3. to analyze algorithms for theoretical and practical efficiency;
4. to probe the optimality of combinatorial algorithms and to develop lower bounds on the difficulty of combinatorial problems.

University of California-Berkeley; Michael A Harrison; **Cryptography and Theory of Computation**; (MCS-8012716); $44,350; 12 mos.

This investigation will bring together a number of disciplines and people and the major funding would bring researchers to

Berkeley for the summer. The common ground of the investigations is in modern communication and complexity theories. The research is into the analysis and application of cryptosystems using complexity theory and probabilistic algorithms. Related problems of a graph theoretic nature will be considered. Other questions that will be investigated are rational best approximations of the second type to a vector of real numbers of the second type, nondeterministic polynomial approximation problems, and combinatorial properties of matrices. Another area will be concurrent programs and large data structures.

Professor Michael Harrison of the University of California, Berkeley will receive a post-doctoral associate as part of the award.

University of California - Berkeley; Richard Karp; **Research in Algorithmic Complexity**; (MCS-7709906A03); $29,835; 12 mos.

This research will concentrate on the probabilistic analysis of heuristic algorithms. NP-hard combinatorial optimization problems will be stressed, but applications will also be sought to problems of speech and image understanding, inference, sequential decision making and game-playing. An investigation of data structure techniques, PSPACE-hard problems and approximation algorithms will also be included.

University of California-San Diego; Te Chiang Hu; **Theory and Computation of Discrete Optimization**; (MCS-8003362); $38,424; 12 mos.

The class of network flow problems is a subclass of linear programming problems, but special algorithms are needed for the network flow problems. Now, there is a subclass C of dynamic programming problems which also needs special algorithms. The dynamic programming needs $O(n^3)$ time to solve the class C while the investigator has developed algorithms requiring $O(n \log n)$ or $O(n^2)$ time to solve many problems in the class C including alphabetic codes, N-order statistics, matrix computation, etc. The investigator will characterize the class C and develop new algorithms and data structures to solve the problems in C.

University of California - San Diego; Stanley G Williamson and Edward Bender; **Combinatorial Algorithms and Asymptotics**; (MCS-7927060); $21,500; 24 mos (Joint support with the Algebra & Number Theory Program - Total Grant $43,000).

Research in combinatorial mathematics is planned. The research is motivated by ideas drawn from modern computer science and related areas as well as strictly mathematical considerations. While both professors have diverse mathematical interests, two areas of immediate concern are (1) combinatorial models for the analysis and description of algorithms, and (2) asymptotic methods in the study of boolean functions and logical gates.

In the case of (1) the purpose of the study is to give combinatorial models for algorithms that provide a global or "geometric" view of the algorithms and, in the case of some data structures, allow for a global or average case analysis of efficiency. At present, algorithms of a topological nature involving planarity questions are being studied. These algorithms are chosen because of the richness and complexity of their recursive structure. The investigators are also studying algorithms involving equivalence relations and algorithms relating the geometric theory of permutations to basic data structures (dictionaries, priority queues, etc.).

In the case of (2) the study involves the application of modern combinatorial asymptotics to the study of canonical forms, generating functions and asymptotic enumeration of fanout-free functions (including those based on gates using multivalued logic). Related to this work, the study of self-diagnosing systems in planned.

University of California-Santa Barbara; John L Bruno; **Stochastic Scheduling: Algorithms And Complexity**; (MCS-8004257); $20,569; 24 mos (Joint support with the Software Systems Science Program - Total Grant $41,137).

The overall goal of this research is to develop mathematical models for the allocation of resources in computer systems, especially models in which job resource requirements are known only probabilistically. Given these models, the investigators are interested in developing efficient scheduling and resource allocation policies which are optimal or near-optimal with respect to some desirable performance measure.

The investigation will be carried on jointly by both Dr. John Bruno of the University of California-Santa Barbara and Dr. Peter Downey of the University of Arizona.

University of Southern California; Chee-Keng Yap; **New Paradigms for Computational Complexity and Related Topics**; (MCS-8005469); $25,483; 24 mos.

Concrete Computational Complexity ought to have a viable concept of "computational problem". The two traditional paradigms of problems, namely, problems-as-functions and problems-as-languages, are inadequate. An alternative paradigm will be investigated. This new paradigm can serve as a theoretical foundation for Concrete Complexity and will be used to investigate two generalizations of comparison-based problems. In one case, the study is of first order problems and in the other case a conjecture of Yao is examined. Open questions and extensions will be studied.

University of Miami; Richard Goodman; **Computer Arithmetic and Applications**; (MCS-8004231); $10,000; 24 mos (Joint support with the Computer Systems Design Program - Total Grant $32,566).

Careful statistical analysis of the error in computer arithmetic can show the dependence of error on important computer design parameters, such as the number of guard digits and whether postnormalization (if any) is done before or after rounding. This allows an informed choice of these parameters. The research focuses on the study of relative error in floating point multiplication, and several measures of error in floating point addition and subtraction.

Northwestern University; Der-Tsai Lee; **Concrete Computational Complexity**; (MCS-7916847); $26,942; 24 mos.

The investigator is proposing research in two areas;

(i) Computational geometry: the development of efficient algorithms to compute proximity and reachability of points in two and three dimensions. Also such questions as constraints and overlapping among N hyperrectangles in K-space.

(ii) Database systems: the design of a database system which facilitates rapid search time in response to queries.

University of Illinois-Urbana; Donna J Brown; **Approximation Algorithms for Resource Allocation**; (MCS-8008854); $23,084; 24 mos.

The principal investigator will use mathematical modeling in order to study resource allocation problems in large computing systems. Motivated by the intractability of these problems, the investigator will develop and analyze efficient approximation algorithms. There are two overall goals the investigator hopes to achieve: 1) the design of more efficient methods for computer resource management, and 2) the extension of these methods to related problems. The investigator will also attempt to derive lower bounds for classes of problems.

Indiana University-Bloomington; Edward L Robertson; **Studies Related to NP-Complete Problems: Structure, Aproximation And Backtracking**; (MCS-8004337); $66,237; 24 mos.

Important practical problems in the class of "NP-complete problems", from such diverse areas as industrial management and computer network reliability, are all difficult to solve, in the sense that all known general methods for solution are not much better than trying all possible cases. Moreover, these problems are all related, so that an efficient solution method for any one problem would provide efficient solutions for all of them. The research under this proposal intends to 1) discover properties characterizing NP-complete problems, 2) study when it is possible to find approximate solutions to NP-complete problems given that finding exact solutions is too costly, and 3) develop methods to ignore hopeless cases if a case-by-case search for solutions is indeed necessary.

University of Kentucky; Frederick R Giles; **Integrality and Combinatorial Optimization**; (MCS-8002987); $3,957; 12 mos (Joint support with the Applied Mathematics Program - Total Grant $7,915).

This research is centered on problems in the area of combinatorial optimization. In particular, the role that integrality plays in the formulation, properties and solution of linear objective combinatorial problems will be investigated. The specific topies to be studied are: 1) total dual integrality for linear systems associated with specific combinatorial structures, including matching forests in a mixed graph; 2) the relationship between total dual integrality and integer round-up properties; 3) the search for efficient, i.e., polynomially time-bounded, algorithms for the determination of maximum weight-sum matching in a polymatroid and for the Chinese postman problem; and 4) the structure of faces of combinatorially-defined polyhedra and its relationship to efficient algorithms for corresponding combinatorial optimization problems.

Massachusetts Institute of Technology; Gary L Miller; **Complexity of Certain Number Theoretic and Graph Theoretic Problems**; (MCS-8007756); $43,168; 24 mos.

The investigation will be into the computational complexity of certain graph theoretic and number theoretic problems. Examples of problems to be considered are: embedding graphs in 2-dimensional surfaces, testing graph isomorphism and factoring integers.

For these problems the investigator will either find reasons to believe that the problems are hard or find more efficient algorithms. In the latter case the algorithms will be applied to other computational problems.

Massachusetts Institute of Technology; Christos H Papadimitriou; **The Complexity of Combinatorial Optimization**; (MCS-7908965A01); $40,869; 24 mos.

The research relates to the development of efficient algorithms for the solution of combinatorial optimization problems. One direction of research is improved approximation algorithms for the traveling salesman problem and some of its variants. The investigation will include some general NP-completeness results concerning certain graph-theoretic algorithmic problems. Several issues related to linear programming in the aftermath of the recent algorithm by Khatchrian will also be examined.

Massachusetts Institute of Technology; Ronald L Rivest; **Concrete Computational Complexity**; (MCS-7805849A02); $80,588; 12 mos.

This is a supplement to a three year grant awarded to Professor Ronald Rivest. The supplement is for the support of a young Polish Theoretician, Andrzej Lingas, whose research interests mesh well with those of the MIT community. In particular, Dr. Lingas is concerned with the problems of Boolean circuit complexity as a way of developing techniques towards resolving the P=NP (polynomial time equals nonpolynomial time) question. Another aspect of Dr. Lingas' research is time/space tradeoffs.

University of Minnesota; Sartaj K Sahni; **Algorithmic Study of Combinatorial Problems**; (MCS-8005856); $47,338; 12 mos.

The research is concerned essentially with the study of combinatorial problems, particularly those arising in graph theory, scheduling theory, design automation, and some branches of operations research. Most of the problems that will be studied are known to be NP-hard. Hence, it is very unlikely that any of them can be solved by an efficient (i.e. polynomial time) algorithm. The investigation of these problems will focus on the following issues:

i) Identify large interesting subclasses of the NP-hard problems that can be solved in polynomial time.
ii) Obtain good heuristics to solve the problem. i.e., obtain algorithms with a good average behavior.
iii) Obtain a characterization of the smallest (or simplest) subclass of the problem that is NP-hard.
iv) Obtain good (and fast) approximation algorithms.
v) Obtain subexponential algorithms for the general problem.

Dartmouth College; Robert L Drysdale; **Algorithms in Computational Geometry and Graph Theory**; (MCS-8002412); $20,010; 24 mos.

Research will be conducted on methods to improve the efficiency of algorithms for several problems in computational geometry and graph theory. The problems include computing the Voronoi diagram for a set of circles, approximating the solution to the traveling salesman problems, finding a clique cut set for a graph, determining if a graph contains an odd chordless cycle, and problems in computer graphics.

Princeton University; Karl J Lieberherr; **Combinatorial Optimization and Search Problems**; (MCS-8004490); $26,507; 24 mos.

The object of this research is to explore the area of combinatorial optimization and search problems, in a continuation of the author's recent work. The general objectives will be:

1. To develop and classify general methods of solving combinatorial optimization and search problems and to classify these problems with respect to their complexity.
2. To apply the general methods to the solution of specific practical problems.
3. To compare algorithms obtained with different methods for the same problem and to analyze the algorithms for theoretical and practical efficiency.

Princeton University; Richard J. Lipton; **Computational Complexity**; (MCS-8023806); $36,100; 12 mos.

This research is aimed at the following questions:

1. How do we construct fast algorithms for a wide class of problems?
2. Why are some problems inherently difficult?

In addition, it is intended to study specific problems of interest to computer science and engineering, namely; model theory, graph isomorphism, etc.

Other problems to be attacked are questions of complexity of certain Turing machine models and RAM models and simulations of nondeterministic Turing machines by deterministic ones.

Columbia University; Ion Filotti; **Algorithmic Problems in the Topological Theory of Graphs**; (MCS-7924401); $38,000; 24 mos.

Algorithmic aspects of topological graph theory will be studied using the methods developed to find efficient algorithms for embedding graphs in surfaces. Among the questions to be studied are: algorithms for embedding graphs in nonorientable surfaces; algorithms for the ismorophism of graphs of a given genus; and obstructions to achieving the embedding of a graph in a surface.

Columbia University; Uri N Peled; **Threshold Functions and Threshold Numbers**; (MCS-8004105); $13,504; 12 mos.

A problem of considerable interest in combinatorial optimization, graph theory, artificial intelligence and logical design of computers is this: given a subset of the vertices of the n-cube, is one linear inequality sufficient to separate it from the complementary subset? If not, what is the smallest number of inequalities necessary? In particular, given a graph on n vertices, this question can be asked about the set of characteristic vectors of the independent sets of vertices. If the smallest number is 1, the graph is called a threshold graph, and these graphs have been characterized. Much less is known about graphs needing 2 inequalities although some results already exist. The investigation will characterize these graphs. It is known for which subgraphs S of a graph G there exists a threshold subgraph G containing S, and the connections between this characterization and matroid theory will be studied. The enumeration of threshold graphs has already yielded new proofs of classical polynomial identities and further such results will be developed. Finally, the investigator will improve the solution methods of 0-1 knapsack problems by using a well-described family of facets of the convex hull of feasible solutions as cutting planes or to obtain good bounds in branch-and-bound algorithms.

State University New York-Albany; Victor Y Pan; **Design and Analysis of Arithmetic Algorithms and Some Applications**; (MCS-8003347); $67,152; 24 mos.

The concern of the theory of arithmetic computational complexity is the design and analysis of efficient arithmetic algorithms for computational solution of numeric problems of practical interest like DFT (Discrete Fourier Transform), filtering signals, matrix multiplications. The work in this area started in the fifties with successful solution of several problems of polynomial evaluation. Since then several classical arithmetic algorithms have been drastically speeded-up, although the acceleration is still far from its known theoretical limits. In particular, the best known asymptotic algorithms for N x N matrix multiplication and inversion (V. Ya. Pan 1979) involves $O(N^{2.6054})$ arithmetic operations vs $O(N^3)$ involved in classical methods $O(N^2)$, the best known lower bound. The late progress in the area (matrix and polynomial multiplications) is based on the study of algebraic properties of the problems and algorithms, in particular, on the study of decompositions of trilinear forms, and or algebraic transformations of some fast but numerically unstable algorithms. Algebraic approach to numeric problems, in particular, as a way of stablizing fast unstable algorithms, seems very promising. The principal investigator will develop new methods of speeding-up the computational solution of non-numeric (combinatorial) problems via the application of fast arithmetic algorithms as this was done by M. Fisher and A. Meyer 1971 for transitive closure problem.

University of North Carolina at Greensboro; Michael Willett; **Analysis of the Graham-Shamir Public-Key Cryptographic System**; (MCS-8004226); $19,663; 24 mos.

The novel concept of a public key cryptosystem, introduced in 1976 by Diffie and Hellman at Stanford University shows promise as a solution to many data security problems. However, the several explicit public key schemes proposed to date will require extensive study before they are certified for actual use.

The principal investigator will focus on the Graham-Shamir public key system, which has been developed to a prototype stage at Bell Laboratories. The analysis of at least two potential attacks on the scheme will be intensified and extended by the principal investigator in the Summers of 1980 and 1981. This research, coordinated with the research of others at MIT and Bell Laboratories, should provide valuable experience with certification methodology for public schemes.

Ohio State University; Boris Pittel; **The Probabilistic Analysis of Combinatorial Problems and Algorithms**; (MCS-8002966); $22,603; 24 mos.

Professor Pittel will study the stochastic behavior of a number of algorithms in discrete mathematics. The algorithms are for the knapsack problem, one of the basic problems in discrete optimization, and for its special case, the partition problem, which calls for generating all partitions of a given integer into distinct summands from a given set. Other algorithms under investigation are for the solution of the set-covering problem and the satisfiability problem in propositional logic, which has important applications to work in artificial intelligence.

This work will be done jointly with Professor V. Lifschitz of the University of Texas, El Paso.

Pennsylvania State University; Helmut Alt; **Computational Complexity of Arithmetic Operations**; (MCS-8003357); $23,612; 24 mos.

Several arithmetic operations, namely number multiplication, division, inversion, and squaring are known to be equivalent with respect to their computational complexity. The investigator recently proved that square rooting also belongs to this class of operations. The investigator conjectures that even more functions, namely all so-called algebraic functions are also computationally equivalent to multiplication. The investigator will use different strategies to investigate this problem.

Pennsylvania State University; Donald B Johnson; **Algorithms and Computational Complexity**; (MCS-8002684); $54,950; 24 mos.

The investigator will invent and analyze combinatorial algorithms. The research will be focussed on finding upper and lower bounds of computation time which coincide as well as obtaining average case statistics for large classes of algorithms.

Some specific areas to be examined are:

1. Quantile information in the presence of given information beyond a minimal problem statement.
2. Characterizing when greedy algorithms make optimal use of resources.

3. Linear expected time selection in X + Y, with applications to statistical computing.
4. Stable sorting in linear expected time.
5. Preprocessing-processing trade offs in sorting and selection.

Pennsylvania State University; Sharon J Laskowski; **The Heuristic Approach to Problems in Computational Complexity**; (MCS-8002681); $22,732; 24 mos.

Many problems in computational complexity have no known efficient algorithms for their solutions. Nevertheless, it is sometimes possible to find heuristic methods which produce adequate solutions quickly. The investigator is studying three uses of the heuristic approach as applied to difficult problems.

The first topic will expand the PI's research on heuristics for tensor ranking by refining and adding to the heuristics for generating upper and lower bounds and analyzing their effectiveness. The notion of ranking approximate tensors will also be investigated. Second, the tensor model will be applied to the compression of digital images prepared for transmission. The last part will involve formulating general heuristics for NP-complete problems, particularly in graph theory.

Southern Methodist University; David W Matula; **Foundation of Finite Precision Arithmetic**; (MCS-8012704); $12,007; 11 mos (Joint support with the Computer Systems Design Program - Total Grant $24,013).

Advances in LSI and VLSI capabilities are fostering an era where complex special purpose hardware for specific application areas will be realizable at acceptable costs. The ability to represent all sufficiently simple fractions and to evaluate reasonably small rational expressions exactly are important features making fixed-slash and floating-slash arithmetic interesting possibilities for special purpose architectures. Previous research has demonstrated that fixed and floating-slash systems are sufficiently competitive in arithmetic logic design requirements and representation and timing efficiencies to be serious candidates for special purpose architectures. The research is directed toward developing and assessing the viability of these arithmetic systems in the most promising areas of application: specifically, (i) assessment of the growth of accumulated error in fixed-slash and floating-slash computations; (ii) investigation of the suitability of these systems for incorporation in symbolic computation packages; (iii) for micro and small minicomputer systems; an assessment of the ability of a single firmware level fixed-slash (or floating-slash) arithmetic package to support moderate user level exact integer, exact rational, and approximate real computation capability; and (iv) investigation of enhancements of particularly extended range for floating-slash and algorithms for special purpose functions such as square root.

University of Texas - El Paso; Vladimir Lifschitz; **The Probabilistic Analysis of Combinatorial Problems and Algorithms**; (MCS-8002442); $18,122; 24 mos.

Professor Lifschitz will study the stochastic behavior of a number of algorithms in discrete mathematics. The algorithms are for the knapsack problem, one of the basic problems in discrete optimization, and for its special case, the partition problem, which calls for generating all partitions of a given integer into distinct summands from a given set. Other algorithms under investigation are for the solution of the set-covering problem and the satisfiability problem in propositional logic, which has important applications to work in artificial intelligence.

This work will be done jointly with Professor Boris Pittel of Ohio State University.

PARALLEL AND DISTRIBUTED SYSTEM MODELS

California Institute of Technology; George J Milne; **Design and Development of a Concurrent Programming Language Based on the Synchronized Behaviour Algebra Model**; (MCS-8019305); $6,226; 12 mos.

The investigation will further develop a model for concurrent computation known as a Synchronized Behavior Algebra. The representation of simultaneous synchronization, using this model, will allow the investigator to represent both hardware and software in a natural way and to carry out the proofs of properties of such systems. The approach is algebraic with the behavior of a system of communication agents being represented by an abstract object; the meaning of the whole being constructed from the meanings of the components using suitable operations.

Georgia Institute of Technology; Nancy Lynch; **Complexity and Computability for Distributed Data Bases**; (MCS-7924370); $55,129; 24 mos.

Automata-theoretic models and discrete complexity measures will be used to evaluate and compare various systems for distributed data base manipulation. The study is intended both to help answer important questions about efficiency of such systems, and also to serve as a protypical case study for development of a formal theory of complexity of distributed computation.

Chicago State University; Richard Johnsonbaugh; **Synthesis and Analysis of Petri Nets and Marked Graphs**; (MCS-8009804); $C; 24 mos (Joint support with the Research Initiation in Minority Institutions Program - Total Grant $24,920).

The focus of this investigation is on the synthesis of Petri nets and marked graphs although the methods to be used are applicable to many problems, including for example, the analysis of nets. Few results concerning the synthesis of Petri nets or marked graphs from prescribed markings are known. The principal investigator, Murata, Koh and Kao have developed several transformations on marked graphs which have proved useful in synthesizing graphs to meet various prescribed conditions. It is expected that the results of this research will considerably extend their methods.

Massachussets Institute of Technology; Harold Abelson; **Information Transfer in Distributed Computations**; (MCS-7924546); $15,642; 24 mos (Joint support with the Computer Engineering Program - Total Grant $30,642).

The investigator will be concerned with the role of communication in computations carried out by large numbers of interconnected elements. The emphasis will be on the inherent complexity of the amount of communication and the pattern of interconnection. Planned work includes determining appropriate complexity measures, developing techniques for establishing upper and lower bounds and investigating the relations with more traditional measures of computational complexity. In particular, these techniques will be applied to problems in areas of distributed computation and VLSI circuit design.

State University of New York-Albany; Peter Bloniarz; **Graph Algorithms in Sequential and Parallel Settings**; (MCS-7804346A01); $24,704; 24 mos.

The object of this project will be the development of efficient algorithms and suitable architectures for solving graph problems on both sequential and parallel processors. An emphasis will be placed on searching-type problems, including the historically important problems of transitive closure (the connectivity properties of a graph), and finding all shortest paths in a graph. The models of computation are standard sequential Algol-like programs, computation in a Boolean network, and parallel structures suitable for implementation in VLSI.

Carnegie Mellon University; J.F. Traub and H.T. Kung; **Parallel Processing and Computional Complexity**; (MCS-7823678A02); $73,599; 12 mos.

The research consists of two parts. The first one deals with deveoping fast parallel algorithms for such problems as garbage collection, game tree searching and parallel database organization. The communication complexity of parallel algorithms is also to be studied. The second part deals with analytic complexity. Information theoretic algorithms will be studied. The distance between these algorithms and optimal algorithms will also be studied.

Rice University; Daniel S Hirschberg; **Parallel Algorithmic Techniques**; (MCS-8003431); $53,852; 24 mos.

The goal of this project is to investigate techniques for implementing algorithms efficiently on a parallel processing system. It emphasizes the development of a suitable realistic model of computation and of developing algorithms for this model that are fast yet have minimal resource requirements. Previous work on this project considered parallel algorithms for graph algorithms. These basic algorithms could be used as subroutines in solving a variety of problems. The model for parallel computation assumed that any number of processors would simultaneously have fetch access to the same location within a large global area. While this model is somewhat theoretic, the algorithms contribute to the basic understanding of how to develop efficient parallel algorithms. A more practical result of this effort was the development of a bucket sort algorithm that assumes a model of computation where no more than one processor can access any one location simultaneously. This research project will continue to introduce further modifications to the model of computation that will result in simulating reality more closely. It will take more factors into the cost accounting, while retaining the capability of complexity analysis.

University of Washington; Michael J Fischer and Richard E Ladner; **Theory of Advanced Computing Structures**; (MCS-8003337); $144,293; 12 mos.

The investigators will develop theory in several practical areas of computing. Goals are to find good abstract models, improved methods, and inherent limitations. Particular topics to be studied include communicating processes, very large scale integrated circuits (VLSI), text editing, and time and space requirements of natural problems.

The work has three main objectives: constructing formal models, finding improved methods, and discovering inherent limitations.

The award includes a one year post-doctoral appointment for Dr. Martin Tompa.

University of Washington; Michael J Fischer, Robert W Ritchie, and Richard E Ladner; **Semantics and Complexity of Computation**; (MCS-7702474A05); $13,092; 04 mos.

The investigation will be concerned with:

1. Time-space trade-offs for sorting on nonoblivious machines.
2. Using alternating machines to understand the power of alternating (nonderterministic) algorithms.
3. A search for polynomial time algorithms for VLSI design.
4. The relationship between sequential time and alternating time.

This is a supplement action which will provide a post-doctorate associate. The candidate, Martin Tompa, is appropriate to the research effort.

ABSTRACT COMPLEXITY; THE LOGIC OF PROGRAMS

Stanford University; Zohar Manna; **The Modal Logic of Programs**; (MCS-8006930); $17,206; 12 mos.

Model logic has been found to be a suitable framework for reasoning. Two formalisms, Dynamic Logic and Temporal Logic, have been suggested; the two are connected, but each has relative advantages and deficiencies. The investigators will evaluate and compare the two formalisms and attempt to enhance each in its weaker points. The ultimate goal is to develop a unified formalism that combines the advantages of both modal-logic systems.

Yale University; Dana Angluin; **Algorithms for Inductive Inference**; (MCS-8002447); $58,037; 24 mos.

The research is in the area of algorithms for inductive inference. The questions would be focused on:

i) formal analysis of heuristics
ii) special classes of languages of functions that are efficiently inferrable

iii) inference from finite sets with no knowledge of nonmembers
iv) state characterization of inference
v) a criteria of simplicity.

Florida State University; Theodore P Baker; **Studies in Computational Complexity**; (MCS-7924583); $14,027; 12 mos.

This award will fund an investigation into:

1) Resource bounded computability.
2) Provability and succinctness in P (polynomial time).
3) Relative computability of functions.

The first of these concerns a polynomial bounded analog of the Kleene arithmetic hierarchy, called the polynomial hierarchy. The polynomial hierarchy will be considered relativized to oracles.

The second will be an investigation as to whether P=NP (polynomial time equals nondeterministic polynomial time) may be an undecidable question.

The last of these deals with the time bounded reducibilities between functions. The principal investigator would like to find a justification of the need of extending the theory of nondeterministic and relative computability.

Purdue University; Francine Berman; **Theoretical and Practical Considerations in Propositional Dynamic Logic**; (MCS-8005387); $24,377; 24 mos.

Propositional Dynamic Logic (PDL) and Dynamic Logic (DL) are formal languages in which we can describe properties of programs such as partial correctness, termination and equivalence. Derived from the classical systems of mathematical logic and model logic, PDL and DL are used as assertion languages for program verification and as formal languages for research in foundations.

The research will extend various aspects of PDL and DL to increase their expressiveness and applicability. This will be accomplished by defining new constructs, expanding and strengthening the underlying support structures of the languages, and exploiting a natural homomorphism with automata.

Purdue University; Carl Smith and Paul Young; **Workshop on Recursion Theoretic Aspects of Computer Science at Purdue University during May of 1981**; (MCS-8007360); $8,500; 10 mos.

The notion of effective computability is central to theoretical computer science and the techniques of recursive function theory have yielded important results. To review the status of this field a conference on the applications of recursion theory to computer science will be held at Purdue University during May 1981. The purpose is to provide a forum for computer scientists who use the techniques of recursion theory in their work and to promote interaction between such computer scientists and recursion theorists whose work is more purely mathematical in orientation. Approximately thirty to forty participants will meet and there will be ten invited speakers.

Harvard University; Harry R Lewis; **Logic, Decision Problems, and Complexity**; (MCS-8005386); $52,581; 24 mos.

The bulk of the research is on the complexity theory of logical decision problems. Specifically, the investigator will study systematically the computational complexity of decidable problems arising out of the classical propositional and predicate calculi. Certain interpreted theories will also be investigated, specifically, Presburger and Skolem arithmetic. There is substantial evidence that the structure of decision problems for these logical systems is intimately related to automata-theoretic and recursion-theoretic complexity theory. A number of particular unresolved extralogical decision problems will occupy the attention of the investigator, for example, the equivalence problem for deterministic multitape finite automata and the calculation of star heights of regular languages.

Massachusetts Institute of Technology; Albert R Meyer; **Logic of Programs and Computational Complexity**; (MCS-8010707); $113,374; 12 mos.

The relations among several programming logics in the literature are considered and a study of their comparative expressive power is undertaken. These Logics include Dynamic Logic (Pratt), Algorithmic Logic (Engeler), Algorithmic Logic (Salwicki), Programming Logic (Constable), and Logic of Effective Definitions (Tiuryn). In computational complexity the investigators will consider the relation between the geometry and accessibility of memory structure, and speed of computation.

Massachusetts Institute of Technology; Vaughan R Pratt; **Dynamic Logic**; (MCS-7804388A02); $68,548; 12 mos.

This research concerns dynamic logic (DL), a recently developed extension of first-order logic catering for processes. This logic is essentially the combination of modal logic (using Kripke binary relation semantics) with Tarski's calculus of binary relations. Among the problems to be considered are:

i Development of axiom systems for propositional dynamic logic (PDL), including axioms for tests and converse.

ii Study of context-free DL (recursive program schemes).
iii Treatment of infinite loops in the nondeterministic case.
iv Treatment of reference within DL.
v Treatment of parallel processing.

Rutgers University; Ann Yasuhara; **Computability on Term Algebras**; (MCS-8009534); $30,283; 12 mos.

The principal investigator is investigating effective methods of computation on finitely generated free (term) algebras that are to be analogous, in each case, to the effective computations on the natural numbers determined by the partial recursive functions. For each case a finitely axiomatizable theory will be found that is just strong enough to represent the class of functions on the particular term algebra computed by the method. Within each such class of functions the investigator wishes to delineate certain subclasses and to relate the various classes to one another in terms of complexity. In terms of the setting thus established the investigator also will consider further work in connection with recursive function theory, logic, finitely presented algebras as congruence classes, relative complexity in terms of coding, and abstract data types.

Clarkson College of Technology; James F Lynch; **Problems in Finite Model Theory**; (MCS-8002695); $21,279; 24 mos.

The research is concerned with mathematical logic of finite structures. The central notion is the set S(o,n) of those structures on {0,1,...,n-1} that satisfy o, where o is a sentence in a formal language and n is a postive integer. The principal investigator will study definability problems of the following kind. Show that there is no o such that for each n, S(o,n) consists of those Q $\underline{=}$ {0,1,...,n-1} which have an even number of elements, where o is a first-order sentence whose atomic formulas are of the form x+y=z, x.y=z, and x in Q with the standard interpretation in {0,1,...,n-1}. Other definability problems in the second-order language of + are equivalent to problems in theoretical computer science: showing that c in Q, and o in the first-order predicate calculus.

Cornell University; Robert L Constable; **The Theory of Programming Logics**; (MCS-7800953A02); $63,964; 12 mos.

Programming logics are formal systems for reasoning about ordinary computer programs. Such logics can be implemented as verification systems and used to test current programming methodologies. This research includes an investigation of this approach. In a more fundamental sense, programming logics can be used to study notions of the complexity of programs since they reflect practical computing techniques. It is in this area that this researchh will have the greatest emphasis.

Cornell University; Juris Hartmanis; **Computational Complexity**; (MCS-7800418A05); $71,138; 12 mos.

This research includes a study of the computational complexity of feasible computations and a related investigation of formally provable computational complexity properties. In particular, the intention is to concentrate on the study of the structure of natural families of computations and the properties and relations between complete problems of these families. As a parallel to this study, will be an investigation of the formally provable properties about complexity of computations and their applications to computational complexity theory.

Cornell University; Juris Hartmanis; **Computational Complexity**; (MCS-7800418A04); $10,928; 12 mos.

Dr. Charles Kelemen of Ithaca College is a member of the Mathematics Department. His research interests are in Theoretical Computer Science, in particular, computation complexity. He will be collaborating with Professor Juris Hartmanis of Cornell funded for the support of research opportunities for visiting small college facility.

New York University; Martin Davis; **Logical Investigations in Computer Science**; (MCS-8002438); $28,000; 12 mos.

Methods of logic play a continuing role in computer science. A central problem in the complexity of algorithms is the problem of determining whether certain Boolean expressions can be given the value "true" by substitutions for the variables. Although this problem is believed to be "intractable," recent work has suggested that improved algorithms for this problem can be constructed by patching together algorithms each of which works well on appropriate cases. Work on the representation of the sets of inputs "accepted" by various automata by corresponding equations in natural numbers will also be worked on. That such representation is possible in general is now well known from the solution of Hilbert's famous tenth problem but little is known about the specific equations that result when restrictions are placed on the automata. Recently introduced coding methods will be used to shed light on this.

State University of New York - Buffalo; Eitan M. Gurari; **Computational Complexity of Certain Decision Problems**; (MCS-8021124; $12,036; 16 mos.

The objectives of this research are: (i) To find nontrivial classes of Diophantine equations for which the Hilbert's tenth problem is decidable; (ii) To obtain different characterizations of Presburger arithmetic together with the complexity involved in related decision questions; (iii) To classify programming languages according to the complexity of deciding the equivalence of programs written in such languages; and (iv) To study decidability properties of counter machines and their relation to decision problems in number theory, logic, and programming variations of auxiliary pushdown automata as well as for other important models of computations.

The Citadel; Stephen D Comer; **A Study of Multivalued Systems and Their Applications**; (MCS-8003896); $15,000; 24 mos.

The investigation will center on problems that cut across the areas of universal algebra, algebraic logic and equational logic. The principal investigator plans to study properties of general algebraic concepts associated with "equational" classes of multivalued systems. The investigation will begin by considering certain multivalued group-like systems (called pseudogroups) and focus on problems that involve multivalued analogues of the notions of congruence, relation, homomorphism, and quotient. Sample questions: Is every pseudogroup quotient of an ordinary group isomorphic to a pseudogroup of double cosets of a group? What is the structure of the class of all "multivalued" congruences on a pseudogroup? The investigation is motivated by an interest in problems about multivalued systems that have applications to the theory of relation algebras and the general theory of semantics for programming languages.

Washington State University; Karl Winklmann; **Dynamic Logic, Overlap Arguments, and Square-Free Strings**; (MCS-8004128); $23,104; 24 mos.

Research is on three topics: Dynamic Logic, overlap arguments, and square-free strings.

Dynamic Logic is a recently developed formalism for reasoning about programs. The goal of the research is to investigate the power of the formalism, especially how it compares to that of other designs and how it is influenced by various programming features.

The purpose of the research on overlap arguments and square-free strings is to identify intrinsic properties of computational tasks which stand in the way of efficient solutions. Here the focus is on computational tasks for which any solution requires a substantial amount of in-storage information transfer activity.

THEORY OF DATABASES

Stanford University; Jeffrey D Ullman; **Database Theory**; (MCS-8012907); $48,067; 12 mos.

This research pertains to theoretical issues in the design of database management systems. A major part of the research concerns the relational data model and properties of certain integrity constraints, called data dependencies, when applied to relations. It is intended to look at concurrent processing of transactions and the enforcement of the serialability condition on concurrently executing transactions and to continue investigations into file organization for partial-match retrieval in query languages.

University of Southern California; Seymour Ginsburg; **The Mathematical Foundations for Relational Data Bases**; (MCS-7925004); $44,000; 24 mos.

In this research a relational data base is considered as the set of all instances satisfying a set of constraints. Constraints involving functional dependencies such as projection, join, and decomposition, and their connection with generating sets and generators have been studied.

This project will involve the examination of new operations and properties such as multi-valued, mutual and join dependencies. Connections between data bases defined by different sets of contraints will be established.

State University of New York-Albany; Daniel J Rosenkrantz; **Design Theory for Database Systems**; (MCS-7803157A01); $32,406; 24 mos (Joint support with the Software Systems Science Program - Total Grant $64,811).

Database concurrency control and mechanisms for database restart and recovery is being studied. Both centralized and distributed systems will be considered, with the emphasis on distributed systems. Besides studying specific designs, proving them correct, and analyzing performance tradeoffs, an attempt will be made to determine which actions or behavior are necessary for correct operation. Criteria for nonserializable concurrency controls will be investigated. In addition, a concurrency control simulator will be programmed.

Various combinatorial problems will be investigated. Problems arising in database systems include predicate satisfiability, optimum location of resources in a distributed system, the processing of queries, and handling deadlocks. Also to be investigated is approximation algorithms for NP-complete optimization problems, concentrating on approximation-preserving reductions between problems.

AUTOMATA AND LANGUAGE-BASED MODELS: FUZZY SETS

University of Alaska - Fairbanks; Thomas J Head; **Context Restricted Generation Systems and the Associated Form Theories**; (MCS-8003348); $42,896; 24 mos.

This project is to study context restricted parallel generation of languages and relations and also to develop form theories for these generation systems and schemes. Transducers and automata are major tools for these investigations and illustrative examples of their application are given. Specific emphasis will be placed on the deterministic generation processes. A rigorous definition of determinism is presented and indications are given that it will be possible to study determinism effectively on the basis of this definition. A definition of form interpretation is given which will allow the development of the form theories and insure that the new form theories relate satisfactorily to existing form theories. The investigator will also pursue classical non-parallel generation processes and search for a unified perspective on both parallel and non-parallel generation.

University of California Berkeley; Manuel Blum; **Complexity Theory and the Study of Automata in Two and Three Dimensional Space**; (MCS-7903767A01); $39,900; 12 mos.

The research pertains to the study of the interaction between simple computers and their environment. The model provides considerable insight into the complex "intelligent" behavior of simple machines in a complex environment. The model has appeared independently in the works of several researchers (including this author) in this country and in Europe, and a rich body of theorems seems just now to be emerging. The expected output of this research should be useful results in the form of interesting algorithms and theoretical insight.

University of California - Berkeley; Lofti A Zadeh; **A Theory of Approximate Reasoning**; (MCS-7905163A01); $15,500; 12 mos (Joint support with the Division of Information Science and Technology - Total Grant $29,500).

This research is aimed at the development of a method of inference from imprecise or unreliable data which are expressed in the form of propositions in a natural or synthetic language. The main application areas for this method lie in the design of expert question-answering systems, decision analysis, and control of robotic systems operating in an imprecisely defined environment.

The approach of this research is based on the representation of the meaning of an imprecise proposition by a procedure which acts on a set of relations in a database and returns a possibility distribution for the variables which are associated with the proposition. The inference rules are applied to the translation of the premises and yield a possibility distribution which upon retranslation becomes an imprecise conclusion inferred from the premises. In general, the premises are allowed to be qualified with imprecisely defined truth values, probability values or possibility values.

University of California - Los Angeles; Jack W Carlyle, Sheila A Greibach and Emily P. Friedman; **Theory of Machines, Grammars and Computations**; (MCS-7804725A02); $64,314; 12 mos.

This research covers several broad areas of theoretical computer science. Included is a study of formal languages with specific interest in Context-free languages. Such languages are often used in defining parts of the syntax of programming languages and examining means for recognizing and parsing context-free languages is important.

A second area of research will concern the semantics of computation. An examination of the semantics or meaning of programs is essential in determining whether tasks written in different languages actually perform the same or optimally. This research will also include a study of parallel computation.

A third area of interest is resource bounded computation. Many computational models allow unbounded resources. These results may not hold for realistic systems where such constraints exist.

University of California - San Diego; Walter J Savitch; **Complexity of Computations**; (MCS-8001963); $66,864; 24 mos.

Research in automata-based complexity will be conducted. One line of research is to study and develop a number of models for the computational complexity of parallel algorithms. A comparison will be made between various models.

Another line of research investigated is that nondeterminism adds significantly to the power of a resource limited device.

A third subject to be investigated is limited nondeterminism and to compare these models to more classical models.

Univ of Cal Santa Barbara; Ronald V Book; **Computational Complexity and Formal Languages**; (MCS-8011979); $30,397; 12 mos.

The goal of this research is to investigate questions in automata based complexity, the representation of complexity classes in terms of language theoretic characteristics, and the classification of functions and predicates by the complexity of their syntactic definitions.

Tools and techniques from the theory of formal languages will be appled to problems in computational complexity, while tools and techniques from the area of computational complexity will be applied to the theory of formal languages.

Northwestern University; Ivan H Sudborough; **Applications of Automata Theory to Computational Complexity**; (MCS-7908919A01); $41,304; 12 mos.

This is a supplement to a two year continuing grant awarded to Professor I. H. Sudborough. The supplement is a small college opportunity grant to be subcontracted to Colgate University. The investigator at Colgate is Professor Michael Evangelist.

Research on the complexity of path problems in graphs and path systems of small bandwidth will be studied. This work has application to classical issues in computational complexity and the design of efficient algorithms. Preliminary work has resulted in new space efficient algorithms for various problems. The work will investigate the effect of small bandwith on NP-complete graph problems, polynomial time complete path system problems, and nondeterministic logarithm space complete graph problems.

U of Kansas Main Campus; Giora Slutzki; **Extensions of Macro Grammars and Stack Controlled Machines**; (MCS-8024341); $10,975; 12 mos.

The research is in the area of Formal Languages and Automata Theory. Basic extensions of classes of languages are defined by extending the power of basic macrogrammars in allowing languages (out of some class) to be passed as parameters. The concept of stack controlled machines is introduced and its connections to basic extensions are studied. The principal investigator will study the existence of "nesting hierarchy" in nested stack automata and its relations to basic extensions.

Johns Hopkins University; S Rao Kosaraju; **Applications of Basic Theory of Computing**; (MCS-7905163A01); $32,961; 12 mos.

This research is concerned with the application of automata and other basic areas to more practical problems in computing. The problems selected are from the design of sequential and parallel algorithms, simulation of data structures and information retrieval.

1) The inter-relationship between common data structures like stacks and double ended queues (deques) will be investigated,
2) The development of data structures and algorithms for searching a dictionary will be studied and

3) The application of known techniques of parallel processing to image processing as well as new design techniques applicable to parallel processing of arrays will be investigated.

University of Minnesota; Oscar H Ibarra; **Complexity of Computation**; (MCS-7801736A02 & A03); $64,073; 12 mos.

The research is in the area of computational complexity. The problems to be considered are the following:

1) Investigate some of the important questions concerning the relationships between nondeterministic and deterministic resource-bounded computations as well as trade-offs between resources.
2) Look for results which show the power of nondeterminism in simple computing devices.
3) Develop techniques for showing the solvability (or unsolvability) of some important decision problems in automata theory, formal languages, program schemes, and other combinatorial and non-automata-theoretic decision problems.
4) Study the computational complexity of some number-theoretic problems. In particular find large classes of polynomials (or systems of polynomials) for which Hilbert's tenth problem is solvable.
5) Find good heuristics for obtaining approximate solutions to computationally difficult problems and identify those problems that admit (fully) polynomial time approximation schemes.
6) Look at the problem of generating near-optimal cliques in graphs by polynomial-time probabilistic algorithms.

City University of New York (Queens College); Bret R Tilson; **Structural Hierarchies of Semigroups and Recognizable Sets**; (MCS-8003595); $13,300; 24 mos (Joint support with the Algebra & Number Theory Program - Total Grant $26,600).

The goal of this research is to establish structure theories for finite semigroups and recognizable sets of automata theory that correspond with one another through the mechanism of the syntactic semigroup of a set.

State University of New York-Albany; Harry B Hunt; **Topics in the Complexity and Practical Provability of Discrete Computation Models**; (MCS-8003353); $48,848; 24 mos.

The investigator will study the complexity and practical provability of various discrete computation models including automata, programming languages, concurrency controls, and relational data bases. The investigator will also consider the questions --

1. What is the inherent complexity of recursive programming languages due to the structures of recursion, test, and assignment, independent of the actual predicates and functions of the language?
2. What properties of structures makes proving their correctness feasible?

When possible, the complexity of problems will be related to their underlying combinatorial structures.

Pennsylvania State University; Gerard Lallement; **Finite Prefix Codes**; (MCS-8001558); $12,100; 24 mos (Joint support with the Algebra & Number Theory Program - Total Grant $24,300).

The research planned involves applications of semigroup theory to the theory of languages.

A prefix code C on an alphabet A is a subset of the free monoid A* that has the unique decipherability property and allows instantaneous decoding by left to right reading. There is a strong connection between the combinatorial properties of the finite codes C and the structure of the transition monoid M(C*) of the minimal automaton recognizing the language C* generated by C. In this context, the following problems will be studied:

1) Find a convenient algorithm to construct all the finite prefix codes such that M(C*) is a union of groups.
2) Determine the indecomposable codes that do not admit a synchronizing word among the codes constructed in 1.
3) Extend a method of constructing some special finite biprefix codes discovered recently by the principal investigator to a general construction.
4) Utilizing finite prefix (or biprefix) codes characterize several varieties of rational languages admitting syntactic monoids that are unions of groups or belong to several more general classes.

The solutions to these problems would contribute substantially to a general knowledge of the nature of the maximal subgroups of M(C*), the mechanism of code decompositions, and the role of finite codes in the theory of regular languages.

Utah State University; James C Bezdek; **Optimization and Validity Tests for the Generalized C-Varieties Clustering Algorithms**; (MCS-8002856); $32,880; 24 mos.

A large class of infinite families of generalized or weighted c-varieties clustering algorithms have been recently discovered. These algorithms appear to hold great promise for many applications (for example, character recognition). There are, however, several fundamental questions related to these procedures which when answered, will greatly enhance their potential utility. This investigation requests funds to support extensive research concerning several unresolved questions about these algorithms. Specifically, a detailed study of performance otpimization, the goal of which is to select the particular family and algorithm thereof which is best suited to use with a specified type of data. Further, an exhaustive investigation concerning measures of validity of solutions generated by these clustering algorithms. The research involves both theoretical and computational components: any new techniques developed will be tested and compared to existing methodologies using real data drawn from the fields of irrigation engineering, geological sediment vectoring, and character recognition.

SOFTWARE SYSTEMS SCIENCE

PROGRAMMING LANGUAGES AND COMPILERS

Univ. of California-Berkeley; Susan L. Graham; **Programming Language Implementation**; (MCS-8005144); $62,975; 12 mos.

The project will comprise both a continuation of ongoing research and an initiation of new investigations pertaining to interactive programming environments. The study of techniques for producing portable compilers; in particular, the development of table-driven methods for the synthetic (i.e., code-generation) phase of compilation will be continued. The table-driven algorithm will be embedded in a complete compiler, both in order to test the feasibility of the technique as a practical tool and to compare it with other designs for retargetable compilers. The LR error recovery technique in the Pascal compiler will be compared with the methods recently developed by other researchers. The compiler technology that has been developed will also be extended to the design of other programming tools, such as editors, debuggers, and program transformation systems. The goal is to facilitate the production of source-language-knowledgeable tools which take their language knowledge from a data base that can be changed readily, thereby "porting" the tool to another source language while maintaining a familar user interface. Finally, some of the particular problems that arise in the implementation of the recently announced programming language ADA will be investigated.

Univ. of Southern California; Robert M. Balzer and David Wile; **Supervisory Control of Transformational Implementation Systems**; (MCS-7918792); $100,527; 12 mos (Joint support with the Software Engineering Program - Total Grant $201,054).

This project is aimed at the long-term development of Transformational Implementation Systems. The work falls into two categories, systems building and fundamental research. The systems building activity provides essential support as a means of building an experience base for developing the insights and perceptions which guide the research and as an experimental vehicle for testing ideas and hypotheses.

The ultimate system is presently seen as having five sets of facilities:

(a) facilities to impose a structure on transformation selection and application, involving planning subsystems, documentation subsystems and maintenance subsystems.
(b) facilities to prove applicability criteria of properties of transformations. Transformations may be applied before some properties are proved applicable necessitating subsequent proof of such properties by inference or symbolic execution or via a general purpose theorem prover or a special purpose property prover.
(c) facilities to do automatic program simplification and to provide automatic application of low level transformations that seek canonical forms.
(d) facilities for combining individual transformations into layer coordinated packages.
(e) facilities to generate new transformations for the catalog on the basis of interactive user editing of the state of the program being generated.

Illinois Institute of Technology; Thomas W. Christopher and Martha W. Evens; **Distributed Compilers for Distributed Systems**; (MCS-8004114); $65,359; 12 mos.

The proliferation of distributed computing systems has brought about a new kind of software crisis. The development of distributed hardware has far outstripped the development of the necessary software. There is a strong need for compilers which translate high level languages into machine code. To make distributed computing systems self-sufficient such compilers must both run on a distributed system and generate code for that same system. The development of such compilers presents two novel problems: how to organize the compiler itself into small modules that run in parallel and how to partition the code into clusters of tasks small enough to fit into the separate computers of the distributed system. This project will carry out research on the problems of distributed compilers for distributed systems: the problem of distributed compiler organization and the problem of distributed code generation. This research will consist of three parts: a theoretical attack on the code partitioning problem, evaluation techniques to compare various partitioning methods, and actual development of distributed compilers for high level languages.

CUNY City College; Valetin Turchin and Charles Weldon; **A Supercompiler System Based on the Language REFAL**; (MCS-8007565); $100,000; 24 mos (Joint support with the Research Initiation in Minority Institutions Program - Total Grant $150,000).

This project will create an experimental model of a programming system which uses the language REFAL as the metalanguage for semantic definition of algorithmic languages. The purpose of this system is to facilitate the creation and implementation of new application-oriented programming languages at low expense, and to perform in a computer a great deal of work on optimization of algorithms, and even on the algorithmization itself, which is now performed by man. The user of the system will have to formulate only the definition of his problem, its mathematical model, without bothering about the details of algorithmic efficiency and data structures in the real computer. The core of the system is a program called "supercompiler", which transforms a multi-level semantic definition of a problem in REFAL into an efficient computer program. The supercompiler itself will be written in REFAL, and this will give the possibility not only to efficiently use just introduced ad hoc languages, but also to produce automatically efficient (compiled) compilers for them.

New York University; Jacob T. Schwartz; **Optimization of Very High Level Languages**; (MCS-8004349); $144,500; 12 mos.

Building on the success of the present global analysis and data-structure choice algorithms of the SETL system, these techniques will be extended to three related areas:

1. Application of global analysis techniques to improved static methods of program debugging;
2. Development of a partially extensible optimizer, able to handle user-defined object types in terms of their logical significance rather than their internal structure;
3. Automatic choice of data structures from a broader range of possibilities, including high-efficiency use of lists and B-trees.

University of Rochester; Jerome Feldman and James R. Low; **Advanced Compiling and Distributed Computing**; (MCS-7902971A01); $66,785; 12 mos (Joint support with the Intelligent Systems Program - Total Grant $133,570).

The goal of this project is to increase our understanding of the problems of "intelligent compiling" in which is to be included not only traditional optimization techniques, but also use of heuristic techniques from artificial intelligence to choose algorithms and data structures, and generally improve programs written in a high-level language. A particular area of concern is the programming and validation of loosely-coupled systems such as those that arise in distributed computing.

SUNY at Stony Brook; Peter B. Henderson; **A Study of Program Transformations**; (MCS-8006531); $62,854; 24 mos.

A transformation on a program may be viewed in many different conceptual ways. Source-to-source transformations, intermediate code optimization, flowcharting and even the program development process itself may be considered to be transformations on "real" or "abstract" programs. We are interested in utilizing the concept of a transformation to help better understand some theoretical and practical problems in current programming methodology. We approach this study in three ways. First, we seek to extend the results of our previous work on transformations of deterministic schema models to non-deterministic models, with an emphasis on Dijkstra's guarded command schemas. The second aspect of this investigation will be to examine some new applications of concepts and techniques developed primarily for code optimization. In particular, known results regarding reducible flowcharts will be used to develop tools that can aid in the design, testing and evaluation of software systems. Finally, the relationship between program transformations and software metrics will be studied. This includes transformations which induce new metrics, and the use of metrics to measure the merits of data abstraction techniques.

Syracuse University; Nancy J. McCracken; **Typechecking and Implementation Properties Of Programming Languages With Extended Type Structure**; (MCS-8004219); $40,055; 24 mos.

This project will investigate typechecking and implementation properties of fully-typed programming languages that extend type structure to include several language features of current interest in programming language design. These features include polymorphic functions (functions that may accept types as parameters), abstract data types, type generators (types that may accept types as parameters), and a variety of constructed types, including recursively defined types.

University of Utah; Gary Lindstrom; **Higher-Level Control Description in Programming Languages**; (MCS-7803832A01); $68,684; 24 mos.

The components of a modern higher-level programming language may be divided into two categories: the data-related, dealing with data structures and their direct manipulation, and the control-related, dealing with overall program logic and the management of run-time environments. A fundamental problem in the latter category is that of control description. This research project is aimed at techniques for control description operating at the extra-syntactic level, where the language design is fixed and the particular program syntactical organization is known. As a concrete language setting for this investigation, coroutines operating in a block structured environment were chosen.

Anticipated benefits include: an assertion language for describing control event sequences; a new framework for systematic program testing; language independent specifications of control disciplines such as nonforgetful searching; new styles of coroutine usage, and tuneable implementations offering greater economies to programs obeying known control event patterns.

University of Virginia; Terrence W. Pratt; **A Formal Theory of Programming Language Definition**; (MCS-7800763A01); $76,479; 24 mos.

A complete formal theory of programming language definition has been developed and brought to maturity under partial NSF support over the past nine years. Work in the past year has shown that the methods developed provide excellent tools for design, definition, and analysis of languages, and that the definitions can be directly used as implementation specifications. This research project will be continued for two major purposes: (1) to provide for publication of information on the methods and their use to a wide audience, and (2) to support a first effort into the use of these methods for the specification and analysis of the semantics of languages and systems for parallel computations on multiprocessor systems. Related work into the use of the methods for specification of data base systems and for further development of techniques for the formal analysis of language definitions will also be pursued.

Univ. of Wisconsin-Madison; Charles N. Fischer; **Advances in the Theory and Design of Diagnostic, Error Correcting Compilers**; (MCS-7802570A01); $83,552; 24 mos.

Diagnostic compilers are programming language translators which are specially enhanced to aid in the rapid detection and correction of programming errors. This project will investigate a number of topics in the design, implementation and automatic generation of components of such compilers.

Methods of improving the accuracy of automatic correction algorithms will be studied. These will include utilization of extended context in making correction decisions, use of specially tailored parsing techniques to anticipate possible user errors and extensions to common correction models. The use of semantic information in the correction process will also be investigated.

Experiments that study the kinds and frequencies of user errors will be continued. The data so gathered will be used to "fine-tune" the facilities provided by diagnostic compilers.

Finally, the use of diagnostic techniques in language-specific program editors will be considered. A prototype editor, already under construction, will be provided with a number of diagnostic facilities. The design and effectiveness of such facilities in an interactive environment will receive special attention.

OPERATING SYSTEMS

University of Arizona; Peter J Downey; **Stochastic Scheduling: Algorithms And Complexity**; (MCS-8004679); $15,906; 24 mos (Joint support with the Theoretical Computer Science Program - Total Grant $31,812).

The overall goal of this research is to develop mathematical models for the allocation of resources in computer systems, especially models in which job resource requirements are known only probabilistically. Given these models, the investigators are interested in developing efficient scheduling and resource allocation policies which are optimal or near-optimal with respect to some desirable performance measure.

This investigation will be carried on jointly by both Dr. John Bruno of the University of California-Santa Barbara and Dr. Peter Downey of the University of Arizona.

Univ of Calif-Berkeley; Michael L. Powell; **Multi-Microcomputer Operating Systems**; (MCS-8010686); $42,000; 24 mos.

The purpose of this project is to develop an understanding of how complex functions such as those found in operating systems may be partitioned among several processors. The information flow between and within operating system components will be examined and experiments will be performed to evaluate the suitability of different locations for boundaries between processes, as well as different assignments of processes to processors. By making such measurements over a wide range of configurations, where a computational task should be segmented, where parallelism is exploitable, and where it is not profitable to share the workload among processors will be determined. The work will be done in Model, a programming language that has facilities for controlling, structuring, and monitoring the flow of information within a program.

University of California-Santa Barbara; John L Bruno; **Stochastic Scheduling: Algorithms And Complexity**; (MCS-8004257); $20,568; 24 mos (Joint support with the Theoretical Computer Science Program - Total Grant $41,137).

The overall goal of this research is to develop mathematical models for the allocation of resources in computer systems, especially models in which job resource requirements are known only probabilistically. Given these models, the investigators are interested in developing efficient scheduling and resource allocation policies which are optimal or near-optimal with respect to some desirable performance measure.

The investigation will be carried on jointly by both Dr. John Bruno of the University of California-Santa Barbara and Dr. Peter Downey of the University of Arizona.

Colorado State University; Dale H. Grit; **The Design and Implementation of an Expression-Oriented System Programming Language**; (MCS-8003306); $46,924; 24 mos.

The implementation of operating systems has always been a difficult, error-prone task. Recently, higher level languages have improved this situation considerably. The use of an expression-oriented language may result in further improvement in the ease of systems programming and in the reliability and verifiability of systems programs. The goal of this project is to develop a systems programming language which is expression-oriented. This will be accomplished by combining existing fragments and new components into a cohesive, consistent programming language. This language will be implemented on a minicomputer to test its applicability and usefulness. The resulting language will be an alternative means for systems programming, providing a convenient tool for the design and implementation of systems with high reliability.

Indiana University; David S. Wise and Daniel P. Friedman; **Applicative Programming for Systems**; (MCS-7722325A01); $88,062; 24 mos.

This project extends the application of applicative programming style in which all computer demands must be expressed as expressions (where arguments act as input and evaluation yields the only output). Specifically we explore the implementation of a new data structure , a multiset, whose order is unspecified when it is constructed but behaves like a conventional ordered data structure upon access. Its order is determined by the convergence of the computations of its constituent elements, and so it is quite useful for synchronization in a complex computer system of several processors (or external events), each associated with one element.

Iowa State University; Dennis G. Kafura; **A Reference String Sampling Technique for Time-Critical Systems**; (MCS-7902970A01); $9,335; 02 mos.

The goal of this research is to discover what, if any, relationship exists between the performance and software structure metrics for a large-scale system. Such relationships, if found, would be important to system designers who are typically faced with selecting the proper balance between system performance and software quality. The performance measurements used in this study will be derived by a reference string sampling technique. The structure metrics which will be used are based on the information flow method developed by Dr. Sallie Henry. Under the Small College Research Participation Program Dr. Henry will conduct the research.

Univ of Wisconsin-Madison; Robert P Cook; ***MAKER -- A Software Implementation Tool for Distributed Systems**; (MCS-8003341); $62,202; 24 mos.

Distributed programming is characterized by high communication costs and the absence of shared variables and procedures as synchronization tools. *MOD is a language, derived from MODULA, which is intended for systems programming in the network environment. *MAKER is a systems implementation tool, based on *MOD, which attempts to address problem areas in distributed programming by creating an environment conducive to efficient and reliable network software construction. The *MAKER system includes program packages for compilation, debugging and software maintenance as well as performance evaluation and modeling.

DATA BASE SYSTEMS

Univ of Illinois-Urbana; Yehoshua C. Sagiv; **Design and Optimization Problems in Relational Database Theory**; (MCS-8003308); $68,050; 24 mos.

The relational model for databases was suggested by Codd in 1970. This model is highly abstract and does not rely on a particular implementation. As a result it is similar to other data structures (e.g., stacks, queues, etc.) that provide data independence, i.e., separation between the logical level and the physical level (i.e., implementation). The relational model is a tool for expressing complicated relationships between the elements of the data, and for formulating queries about those relationships. This model offers structure alternatives on a logical level, and it is needed when the data is not a simple set. Although it is not perfect, the relational database model offers much power for little mechanism and in this respect it is similar to context free grammars. Interesting issues to be investigated include database design with multivalued dependencies, and optimization of queries given a design.

State University of New York-Albany; Daniel J Rosenkrantz; **Design Theory for Database Systems**; (MCS-7803157A01); $32,405; 24 mos (Joint support with the Theoretical Computer Science Program - Total Grant $64,811).

Database concurrency control and mechanisms for database restart and recovery are being studied. Both centralized and distributed systems will be considered, with the emphasis on distributed systems. Besides studying specific designs, proving them correct, and analyzing performance tradeoffs, an attempt will be made to determine which actions or behavior are necessary for correct operation. Criteria for nonserializable concurrency controls will be investigated. In addition, a concurrency control simulator will be programmed.

Various combinatorial problems will be investigated. Problems arising in database systems include predicate satisfiability, optimum location of resources in a distributed system, the processing of queries, and handling deadlocks. Also to be investigated is approximation algorithms for NP-complete optimization problems, concentrating on approximation-preserving reductions between problems.

FORMAL STRUCTURE OF PROGRAMS

Stanford Research Institute; Richard J. Waldinger; **The Automatic Synthesis of Computer Programs**; (MCS-7802591A02); $89,810; 12 mos.

Program synthesis is the derivation of a computer program from given specifications. The specifications express the purpose of the desired program in terms of high-level constructs, without giving any hint of the method by which that purpose is to be achieved. The basic approach is to transform the specifications repeatedly according to certain rules. Each rule replaces one segment of the program description by another equivalent segment, until a description is obtained that is entirely in terms of the target language.

Several basic program-formation principles have already been identified, represented as transformation rules, and incorporated into an experimental implementation. This system constructs simple LISP-like programs for list processing, numerical computation, and set manipulation. The principles that have already been developed include the formation of conditional expressions and recursive calls.

The current phase of the research is focused on the formation of systems of many procedures, the generalization of programs, and the construction of programs with indirect side-effects, as well as the application of these techniques to other aspects of programming methodology. The techniques developed are being incorporated into the experimental system.

Stanford University; Donald E. Knuth; **Analysis of Algorithms**; (MCS-7723738A02); $167,712; 12 mos.

The present program of research in the Analysis of Algorithms will be continued. The research is oriented toward an improved quantitative understanding of the fundamental algorithms of computer science, and it comprises five major activities:

(i) Development of new, efficient methods for use on computers.
(ii) Analysis of the performance of important computer techniques.
(iii) Analysis of the computational complexity of problems.
(iv) Studies of programming languages.
(v) Combinatorial theory to support the above activities.

Stanford University; Zohar Manna; **A Deductive Approach to Program Synthesis**; (MCS-7909495); $63,814; 12 mos.

Program synthesis is the systematic derivation of a program from given specifications. This specification constitutes a high-level description of the desired program which expresses the purpose of the program, without indicating the method by which that purpose is to be achieved. A deductive approach to program synthesis will be used for the construction of recursive programs. Such an approach regards program synthesis as a theorem-proving task and relies on a theorem-proving method that combines the features of transformation rules, unification, and mathematical induction within a single framework.

This project will focus on:

1) Development of subsidiary procedures; construct systems of procedures that form together the desired recursive program.
2) Generalization of programs; extend the given specification to represent a more general problem that is, nevertheless, easier to solve.
3) Construction of program with side effects; construct programs that can change the values of variables and manipulate other data structures.

University of Southern California; Ellis Horowitz; **Improved Software Reliability via Axiomatic Specification of Data Structues-II**; (MCS-7801798A04); $67,542; 12 mos.

This study is concerned with developing improved techniques for design and verification of software. In particular the concentration is on the design of data structures, which design is an integral part of every software system. The point of view is to continue to develop a notation for rigorously specifying a data structure without implying anything about its eventual representation in a computer. This has the advantage of allowing the designer to concentrate on each task separately, thus controlling the complexity of the process and hence improving the reliablity of the end result. This kind of specification can also be instrumental in proving the correctness of an implementatation of the design, thus providing a second advantage to this approach. Other promising possibilities suggest themselves and are outlined within the proposal.

Indiana University; Mitchell Wand and Daniel P. Friedman; **Algebraic and Logical Semantics of Computation**; (MCS-7904183); $98,043; 24 mos.

The introduction of formal techniques for proving that a program module meets its specifications has been an important development in computer science. Such formal techniques must rely on a formal statement of specifications, expressed in a formal specification language. Although a number of different specification techniques have been proposed, none provides a unified logical theory comparable in breadth and depth to that of first-order predicate calculus. The goal of the research is the study of the logic of specific languages. This should shed light on the distinction between "implementation" and the conventional mathematical notion of a model.

Massachusetts Institute of Technology; Rohit J. Parikh; **Logics of Computation**; (MCS-7910261A01); $53,451; 12 mos.

This project will continue the study (1) a decidable second order logic of processes, SOAPL, which generalizes several previously proposed formal logics of programs, and (2) the kinds of assertions expressible in different variants of V. Pratt's dynamic logic, in comparison to those expressible in other formal logics of programs as well as the infinitary logic L_{w_1w}.

There are also more ambitious ancillary goals like the modelling of parallel processes, probabilistic computation, questions of vagueness, and the relationship between dynamic logic and Scott-type semantics.

Univ. of Massachusetts; Michael A. Arbib and Ernest G. Manes; **Partially-Additive Semantics of Programming Languages**; (MCS-8005112); $79,997; 24 mos.

Research on partially-additive semantics has already achieved the following: a simple characterization of sequential composition, generalized conditionals and iteration; a series expansion for any abstract recursion scheme which yields a canonical fixed point, and which is amenable to algebraic manipulation for proofs of correctness; and an interpretive semantic which may be proved to be an instance of the canonical fixed point.

This project has three components: to provide a proof rule approach to proving program correctness which is founded in a partially-additive semantics; to explore the limits of applicability of the new methodology by using it to model declarations and data structuring, and to provide a semantics for PASCAL, LISP, APL and ADA; and to use techniques from category theory to provide a foundational approach linking partially-additive semantics to process and dynamic logics.

Washington State Univ; David B. Benson; **Algebraic Structures for Computer Programs in Program Specifications**; (MCS-8003433); $86,488; 24 mos.

This project will investigate the denotational semantics of nondeterministic and parallel programming languages as well as nondeterministic and parallel specification techniques. A particular objective is the development of well-founded methods of reasoning about programs and formal specifications which are crisp and easy to understand. Algebraic methods will be applied to the study of programming languages with certain semantic features -- various forms of nondeterminism and parallelism. This will indicate that well-founded domains of algebraic reasoning can become useful to programmers and specifiers in the near future.

CONCURRENCY

University of Arizona; Gregory R. Andrews; **Synchronizing Resources: An Approach To Programming Concurrent Systems**; (MCS-8001668); $75,067; 24 mos.

As a result of the continuing proliferation of new hardware architectures and applications it has become increasingly important to develop programming languages that allow the software for these systems to be developed effectively. Several major advances have occurred recently, but each new parallel programming language is based either on the monitor (share variable) concept or on the message passing (no shared variable) concept. This project investigates a new language, Sychronizing Resources, that synthesizes these concepts and also contains some novel mechanisms for structuring, synchronizing, and scheduling systems of parallel processes. The project examines several topics that need to be studied in order to assess the utility of the new language. In particular, the research addresses: applications of the language to conventional operating systems, communication systems, and data bases; semantic properties of the language including correctness, absence of deadlock, and absence of starvation; implementation issues that affect efficiency of execution; and possible extensions that are suggested by the other topics.

Massachusetts Institute of Technology; Barbara Liskov; **Primitives for Distributed Computing**; (MCS-7923769); $133,881; 24 mos.

Distributed programs that run on nodes of a network are now technologically feasible, and are well-suited to the needs of organizations. However, our knowledge about how to construct such programs is limited. This project will carry out research in the construction and structure of distributed programs. Primitives that support distributed programming will be designed and provided for use as part of a programming language. That language will be used to experiment in writing distributed programs. The experiments will lead to refinements in the language. The ultimate goals are a deep understanding of distributed programs, and the definition and implementation of a programming language incorporating that understanding in a set of linguistic features well suited to the writing of distributed programs.

Drexel University; Richard M. Salter; **Toward a Methodology for Multiprogrammed Nondeterminism**; (MCS-8004130); $25,000; 24 mos.

Nondeterministic algorithms are important models used to formalize the search procedure usually implemented by backtracking. Recent results have addressed the nondeterministic model itself, apart from any deterministic implementation, and have generated interest in the utilization of a broader scope of implementation strategies. An important computational technique which deserves consideration is the use of parallel searches in the tree of partial computations. Such an application has become feasible due to the development of appropriate concurrency tools at various levels.

The goal of this research is to study how single processor backtracking may be improved by the use of multiprocessing. We will attempt to discover the software tools appropriate for expressing the design of this class of concurrent processing problems. We will utilize the various models of concurrency in the design of a methodology which is less dependent on deterministic translation, and which will lead to a more versatile and efficient realization.

PROGRAM VERIFICATION

SRI International; Robert Boyer and J. Strather Moore; **Mechanizing the Mathematics of Computer Program Analysis**; (MCS-7904081A01); $148,536; 12 mos.

The present line of work has led to the development of an extensible formal theory for reasoning about the inductively constructed objects (e.g., integers and sequences) underlying the semantics of programs, and the development of an automatic theorem-prover for that theory. One measure of the success of the work to date is the list of difficult programs proved correct by the system: a simple optimizing expression-compiler, an expression-parser, a fast string-searching algorithm, a mechanical theorem-prover for propositional calculus, and an arithemtic simplifier. The deepest theorem proved thus far is the unique prime factorization theorem, which is derived entirely from the Peano axioms for integers and lists and previously proved theorems. Improvements to both the theory and the proof techniques will be pursued. These improvements will make it easier to state and prove many kinds of assertions (e.g., by providing recursive, schematic concepts), will ease the burden on the user during proofs (e.g., by mechanically inventing lemma), and will increase the system's competence on many important domains (e.g., graphs, the rationals, combinatorics). The utility and feasibility of extending the system with subroutines proven sound by the system will be demonstrated.

COMPUTER SYSTEMS DESIGN

COMPUTER SYSTEM ARCHITECTURE

California Institute of Technology; Carver A Mead; **Industry/University Cooperative Research: Design of Silicon Structures**; (MCS-7826367A01); $40,160; 12 mos (Joint support with the Electrical & Optical Computing Program, the Computer Engineering Program, and the Industry/University Cooperative Program - Total Grant $206,273).

The work of the Silicon Structure Project can be divided into two categories. The first category covers fundamental work directed towards increasing knowledge on subjects germane to integrated circuits design including: representation for design, modeling of physical phenomena in processing, verification of silicon, implementation of systems, development of design rules for stability and the generation of regular structures.

The second category covers the embodiment of this knowledge in computer programs to assist in the design process. These programs will use novel representations appropriate to different phases of the design to build design models that allow simplified checking and verification. They are directed towards producing workable compliers and debugging systems.

The Silicon Structure Project development of VLSI design tools is jointly sponsored by industry and NSF. The industrial sponsorship comes from a number of companies involved in manufacturing computers and semi-conductor components.

University of Central Florida; Amar Mukhopadhyay; **String Processing Computer Architecture**; (MCS-8005096); $111,760; 24 mos.

The principal objectives of this research are the design of hardware algorithms for string processing and the development of string and text processing machine architectures. The primary motivation to investigate such architectures is to overcome the limitations of conventional machines in nonnumeric processing as well as to minimize the effects of the 'von Neumann bottleneck' over a storage hierarchy. Development of such specialized hardware processors, which manipulate large amounts of nonnumeric data on serial access or rotating devices by associative and parallel hardware algorithms, will result in simplification of software systems and provide better response time and reliability at low cost available from current semiconductor technology. Specific tasks of the project are: design of string processing hardware algorithms, development of general purpose string processor based on SNOBOL, and development of backend architectures for textual information bases.

University of Miami; Richard Goodman; **Computer Arithmetic and Applications**; (MCS-8004231); $22,566; 24 mos (Joint support with the Theoretical Computer Science Program - Total Grant $32,566).

Careful statistical analysis of the error in computer arithmetic can show the dependence of error on important computer design parameters, such as the number of guard digits and whether postnormalization (if any) is done before or after rounding. This allows an informed choice of these parameters. The research focuses on the study of relative error in floating point multiplication, and several measures of error in floating point addition and subtraction.

Univ. of Hawaii-Manoa; David R. Stoutemyer; **Scientific Applications of Computer Algebra**; (MCS-7926250); $20,000; 24 mos (Joint support with the Software Engineering Program - Total Grant $79,540).

The overall objective of this research is to develop general-purpose applications of computer algebra and to help make computer algebra useful to a larger segment of the scientific community. As one contribution toward these goals, this research concerns development of a program package which infers closed-form analytic solutions from the leading terms of truncated series solutions. As another contribution toward these goals, the research concerns development of a demonstration prototype hand-held computer-algebra calculator.

Northwestern University; Erwin H. Bareiss; **Probabilistic Error Analysis for Constant Relative Difference and Floating Point Computers**; (MCS-7920150); $35,000; 24 mos (Joint support with the Software Engineering Program - Total Grant $85,963).

The research involves an investigation into the probability distributions of roundoff errors in the four basic arithmetic operations of addition, subtraction, multiplication, and division. These error distributions will be studied for various techniques of representing numbers in a computer including fixed point, floating point and constant relative difference number representations. Application of these distributions to the error analysis of numerical algorithms will also be investigated.

Univ of Illinois-Urbana; David J. Kuck and Duncan Lawrie; **Computer System Organization**; (MCS-8001561); $125,012; 12 mos.

This is a project aimed at moving forward the automation of computer system design on several levels. At the highest level, user Fortran programs are analyzed to obtain a rough idea of machine characteristics that are desirable for their efficient execution. The machines under consideration include those that execute single-array instructions, multiple-array instructions, and multiple-scalar instructions. Correspondences between program constructs and machine structures are measured by the analyzer. The analyzer may be thought of as a compiler prototype for these various machine structures. At the lowest level, the system can be used to accept behavioral descriptions of logic (e.g., sequential machine descriptions). The analyzer can take such a description, process it and map it into a structural description of the logic necessary to execute the behavioral description. As many technological constraints as possible will be incorporated to make this mapping realistic for VLSI circuit design.

University of Illinois-Urbana; James E Robertson; **Theory of Computer Arithmetic**; (MCS-8000058); $43,553; 12 mos.

Research directed toward the design of structures which are in some sense "universal" has led to studies of a module for variable precision arithmetic. A single-precision module can perform arithmetic operations on segments of multiple precision operands serially, or if greater speed is desired, additional modules can be employed in a parallel or serial-parallel mode. The arithmetic operations include addition, subtraction, multiplication, and division. A redundant representation of numbers is necessary, using a signed-digit representation.

This "universal" module concept is being extended to include the DeLugish algorithms for the square root, logarithm, exponential, trigonometric, and inverse trigonometric functions. In addition, the applicability of the concept to the function evaluation tecniques proposed by Ercegovac is being explored.

The design studies indicate a need for complex logical structures for which detailed logical designs are unknown. This, in turn, has led to the recent discovery of an algebra of structures for binary arithmetic. The elements of the algebra are digit sets; an equation represents an arithmetic structure. It is hoped that the algebra will provide a means for concise descriptions of complex structures in much the same way that Boolean algebra is used for logic circuits. Extensions of this algebra to subtraction and other radix are being explored.

Massachusetts Institute of Technology; Jack B. Dennis; **Data Flow Computer Architecture**; (MCS-7915255); $73,369; 12 mos.

The Computation Structures Group is continuing its fundamental research on program structures and computer architecture for data flow computation. Areas being studied include: program transformations to better match program structure to a hypothetical data flow architecture; machine level program structure and code generation; hardware specification, verification and simulation based on an architecture description language for packet systems; and new methodologies for performance estimation and fault tolerance applicable to packet system architectures.

University of Michigan; Daniel E Atkins; **High-Performance, Application-Directed Arithmetic Processors**; (MCS-8007298); $84,593; 12 mos.

The objective of this research is to establish theory and methodology relevant to the synthesis and analysis of high-performance digital computers which are optimized for a given application. Such special-purpose or application-directed machines can provide very cost-effective solutions (in some cases, the only solution) to important computational problems (e.g., real-time, 3-dimensional image processing, weather prediction, numerical wind tunnels).

Since arithmetic is fundamental to high-speed computing, a major component of the project relates to the creation of a computer-based Arithmetic Design System (ADS). This tool is assisting in the quantitative analysis of alternate approaches to implementing arithmetic processors including use of many novel number systems other than the predominant "two's complement". Major components of the ADS include time-space complexity analysis, numerical analysis, formal verification, automatic exploration of structural alternatives, simulation, and interface to computer-aided logic design. The ADS is being applied to design studies in the context of very large scale integrated (VLSI) circuit technology.

The theory and methodolgy developed are being tested empirically by design and prototype construction of application-directed arithmetic processors.

New York University; Jacob T Schwartz; **The VLSI Software Architectures Laboratory Oriented Toward Large-Scale Parallelism**; (MCS-7921258); $157,000; 12 mos (Joint support with the Computer Engineering Program - Total Grant $232,000).

This project addresses one of the most significant opportunities being opened up by the rapid development of LSI (Large-Scale Integration) technology, namely the possibility of organizing parallel computation on a very large scale (e.g. using thousands of processors) especially for purposes of scientific and artificial-intelligence related computation. This program of research on algorithms, hardware architectures, and programming style is underway.

State University of New York - Buffalo; Larry D Wittie; **Communications in Large Networks of Microcomputers**; (MCS-7803166A01); $13,830; 0 mos.

This project is studying the effect of interconnect strategies on the efficiency of message traffic between interacting microcomputer nodes in multicomputer networks. Several connection strategies are being explored.

Mathematical analysis and direct measurement techniques are being used to determine interprocess message requirements for parallel algorithms, especially those used for distributed operating systems controlling microcomputer networks and for simulation of physical systems with the aim of showing which network organizations are best for which large classes of problems.

University of North Carolina-Chapel Hill; Gyula A Mago and Donald F Stanat; **Uses of Memory in a Computer Based on Functional Programming**; (MCS-7802778A01); $122,678; 24 mos.

The potentials of functional programming and the unusual opportunities offered by VLSI technology have motivated several research efforts to create computer systems on completely new foundations. This research is part of an ongoing effort to create a computer system based on the functional programming languages recently described by Backus. A design for a cellular machine capable of highly concurrent evaluation of functional expressions has already resulted from this effort. The fundamental problems involved in coupling memory with the expression evaluator for these languages are being studied. Investigations of automatic couplings (i.e., ones transparent to the programmer) and ones under programmer control are being considered.

Carnegie-Mellon University; S W Director and Daniel P Siewiorek; **Multi-Level Computer Aided Design of VLSI Digital Systems**; (ECS-7825755A01); $83,999; 12 mos (Joint support with the Electrical & Optical Computing Program and the Computer Engineering Program - Total Grant $167,999).

As the advances in integrated technology continue to be made with the realization of larger and more complex circuits on a single chip, it is imperative to consider the entire digital system - integrated circuit design as an overall procedure involving consistent design methodology and computer aids which are required to implement this design methodology. It is the purpose of this research program to develop a design procedure which in this phase includes multi-level synthesis and design, and methods of evaluation and evaluation metrics. Important research that is being considered involves a definition and evaluation methodology for the output design space, the independence of design parameters at one level on objective functions at another, the effect of a set of design parameters at different levels on the total object function, and the formulation of multi-level design optimization procedures and design space search strategies. Performance, cost, reliability, and testing are an integral part of the search for effective evaluation methodology.

The overall design and the consistent computer aids incorporate the flexibility that integrated circuit realizations provide while at the same time recognize the limitations imposed by the integrated circuit technology itself. Provision is being made to accommodate new technology advances.

Pennsylvania State University; Mary J Irwin and Don E Heller; **VLSI Architectures and Algorithms for Recursive Computations**; (MCS-7809126A01); $123,820; 24 mos.

This research focuses on a high speed arithmetic system for recursive numeric computation. The core of the arithmetic system is an online pipeline network. This pipeline network, by chaining on digits (similar to chaining on words as used in the CRAY-1), can support a broad range of recursive computations which have not been amenable to pipeline processing in the past. This pipeline network is also suitable for VLSI implementation. Based on the component technology of the CRAY-1, preliminary analyses show that speedup factors of three to four may be achieved over the CRAY-1 and comparable systolic arrays. It is projected that the online pipeline network approach can provide a significant speed improvement in other, more complex recursive problems as well. Goals of the research are 1) to undertake a detailed architectural design study of the online pipeline network processor and the memory-processor interface, and 2) to investigate other recursive numeric computations which are potential candidates for fast solution on such a system.

Rice University; J Robert Jump; **Interconnection Schemes for High Performance Modular Computing Systems**; (MCS-8001667); $107,350; 24 mos.

The goal of this research project is to investigate the relationship between the performance of modular computing systems and the interconnection structures used for intermodule communication. This is motivated by the desire to make effective use of LSI and VLSI devices as the modules of high performance, parallel computing systems. The project is concentrating on the intermodule connection schemes because they account for a significant part of the overhead encountered in attempting to realize the concurrency present in parallel algorithms. Moreover, this interconnection overhead increases rapidly as the number of modules in a system is increased. For this reason, many of the interconnection methods employed in existing parallel systems are not effective when extended to systems composed of a large number of inexpensive modules. This project is considering various existing and new interconnection structures in order to obtain a quantitative evaluation of how they effect the performance of such systems.

Southern Methodist University; David W Matula; **Foundation of Finite Precision Arithmetic**; (MCS-8012704); $12,006; 11 mos (Joint support with the Theoretical Computer Science Program - Total Grant $24,013).

Advances in LSI and VLSI capabilities are fostering an era where complex special purpose hardware for specific application areas will be realizable at acceptable costs. The ability to represent all sufficiently simple fractions and to evaluate reasonably small rational expressions exactly are important features making fixed-slash and floating-slash arithmetic interesting possibilities for special purpose architectures. Previous research has demonstrated that fixed and floating-slash systems are sufficiently competitive in arithmetic logic design requirements and representation and timing efficiencies to be serious candidates for special purpose architectures. The research is directed toward developing and assessing the viability of these arithmetic systems in the most promising areas of application: specifically, (i) assessment of the growth of accumulated error in fixed-slash and floating-slash computations; (ii) investigation of the suitability of these systems for incorporation in symbolic computation packages; (iii) for micro and small minicomputer systems - an assessment of the ability of a single firmware level fixed-slash (or floating-slash) arithmetic package to support moderate user level exact integer, exact rational, and approximate real computation capability; and (iv) investigation of enhancements of particularly extended range for floating-slash and algorithms for special purpose functions such as square root.

University of Texas-Austin; K. M. Chandy and J. Misra; **Performance and Correctness of Distributed Systems**; (MCS-7925383); $119,871; 24 mos.

This project focuses research on distributed systems in the areas of performance and correctness. In particular, performance models of highly parallel architectures developed under a previous grant will be extended to more general distributed systems. Distributed simulation programs previously developed will be implemented on a distributed simulation test bed. The distributed simulation test bed will prove valuable in evaluating new distributed algorithms for key problems which will be developed and encoded in a suitable communication-process notation. Techniques for proving distributed program correctness which have been developed will be applied and extended. An axiomatic approach to correctness proofs of distributed systems previously developed appears promising and its value on important problems such as communication protocols will be demonstrated. The concept of dynamic priorities previously developed to prove absence of deadlock and proper termination of distributed systems will be extended.

University of Texas-Austin; Gerald J. Lipovski, James C. Browne, and Lyndon Taylor; **Reconfigurable Varistructure Array Processor**; (MCS-7720698A02); $162,779; 12 mos.

A banyan switch is to be used to connect a plurality of microprocessors, memories and I/O devices into a computing system. The banyan switch interconnection has two fundamental advantages: the interconnection structure can be dynamically varied, and the growth in complexity of the switch with number of interconnected elements can go as n ln(n) rather than the n^2 growth of a full cross-bar. The variable structuring capability allows the structuring of architectures to fit applications at run-time. The system characteristics which can be varied include: width and length of memory, the number of processors acting in unison and connection to I/O facilities. The slow growth rate in switch complexity potentially allows the extension to very many system elements. A varistructured architecture clearly holds the promise of effective performance for a wide variety of applications.

The purpose of this project is to demonstrate the feasibility of the variable structure approach and to explore its potential applications. The three major parts of the project are: 1) building and evaluating the banyan switch, which requires graph theoretical studies and simulation, and a special integrated circuit bidirectional amplifier, 2) designing the architecture to incorporate various mechanisms to exploit parallelism (vector operation, pipelining, data flow, and organization similar to horizontal microprogramming) and, 3) designing, building and evaluating the basic software, especially the operating system needed to manage a variable structure and to exploit the several forms of parallelism available in this architecture.

University of Utah; Lee A Hollaar; **Continued Analysis and Development of Specialized Backend Processors for Very Large Text Databases**; (MCS-8021116); $44,969; 12 mos.

As advancing memory technology makes very large databases feasible, it becomes clear that conventional digital computers will not be able to provide satisfactory response time, and specialized machines will be required. While a number of specialized processors have been designed for structured databases (such as those using the relational or hierarchical models), they are not suited for processing text. Two classes of specialized processors can be used to enhance the performance of a text retrieval system--text searchers, capable of rapidly scanning data for specified patterns, and list merging processors, able to efficiently handle the combining of lists which forms the heart of any inverted file system.

This project is continuing the examination of architectures for both classes of machines. Possible machine designs are being explored and simulated, both at the logic design level, to isolate problems in the design, and globally, to determine system operation and scheduling policies and performance. Prototypes of the final system will be constructed to verify the results of the simulation.

University of Wisconsin-Madison; David J Dewitt; **Investigation of Data-Flow Machines for Relational Database Management Systems**; (MCS-7801721A01); $58,902; 24 mos.

The database machine being considered is a specialized computer organization constructed with a large number of inexpensive processors. Such a computer is intended for efficiently processing database queries which access very large databases. A data-flow computer is a computer which uses the presence of data as the criterion for instruction initiation and control rather than the instruction's position in the program. While previous research has shown that the application of data-flow machine techniques to the processing of relational algebra database queries can significantly decrease their execution time, no architecture employing these techniques has been previously designed. This project will focus on the investigation of the properties of such a machine. In addition, alternative organizations for data-flow data base machines, multi-processor algorithms for performing relational algebra operators, and mechanisms for both concurrency control and roll-back and recovery for data-flow database machines will be examined and evaluated.

FAULT TOLERANCE AND RELIABILITY

Standford University; Edward J McCluskey; **Reliable Computers**; (MCS-7904864A01); $76,856; 12 mos.

Research aimed at developing a basic understanding of the techniques for designing reliable computers is the focus of this project. The major objective is to develop and describe systematic techniques for designing testability into digital networks and systems. The closely related problem of the interaction between the testability aspects of individual chips and modules, and system strategies for testing, rollback, and reconfiguration is also being investigated.

University of South Florida; Kwang H. Kim; **Automatic Error Recovery in Distributed Computing Systems**; (MCS-8012906); $39,466; 17 mos.

The objective of this research is to explore a new approach to error recovery in distributed computing systems. When each process in a distributed system is designed to attempt recovery through rollback and retry, rollback of one process may cause rollbacks of other processes that interacted with the former. In the worst case, an unnecessary and disastrous avalanche of rollback propagations among processes may occur just because the recovery-points of the processes are not well coordinated. In contrast to the previously studied approaches which require the program designer to carefully specify the recovery-points of interacting processes, the approach being explored is to provide the capability in the underlying processor system of automatically coordinating processes for prevention of unnecessary rollback propagations. Results of the preliminary study indicate the logical soundness of the programmer-transparent (or machine dependent) approach and a direction for its practical implementation in systems structured by powerful language tools - recovery block and monitor. The programmer-transparent approach is not exclusive to but rather complementary to programmer-dependent approaches. Therefore, this project specifically aims at 1) the development of cost-effective implementation techniques for the programmer-transparent approach and 2) the logical extension of the approach toward incorporating some attractive features of a programmer-dependent approach, again, in a cost-effective way.

COMPUTER SYSTEM PERFORMANCE MEASUREMENT AND EVALUATION

Stanford University; Donald L Iglehart (in collaboration with Gerald S. Shedler, San Jose Research Laboratory, IBM); **Industry/University Cooperative Research: Discrete Event Methods For Computer System Simulation**; (MCS-7909139A03); $50,296; 12 mos (Joint support with Industry/University Cooperative Program - Total Grant $101,185).

This research is for the development of rigorous theoretical foundations for discrete event digital simulation. Primary motivation for the specific work is the need for firmly based methods applicable to simulations of computer and communication systems which, to a large extent, deal with congestion phenomena. Emphasis is on the development of new mathematical and statistical methods for queueing networks and stochastic point process models pertinent to the design of simulation experiments and the analysis of simulation output. Performance evaluation of computer and communication systems requires such methods.

Colorado State University; Rector L. Page; **Influence of System Components on the Performance of Multi-Processor Computer Systems**; (MCS-8004225); $140,723; 24 mos.

The design and analysis of a model for a multiprocessor system oriented towards the evaluation of recursive programs comprise the primary goals of this project. Specific steps towards these goals include: a study via simulation and analysis of a multiprocessor model which extends a model developed in previous work; a study of switch configurations compatible with the model and their effect on performance; a study of trade-offs among different choices of instructions for the basic instruction set of the processing elements in the system; a study of coding techniques oriented towards this model; compactification of the process hierarchy recorded for the purpose of deleting irrelevant processes from the system; a study of trade-offs between task duration and the spawning of tasks in the system; a study of the use of explicit, programmer controlled specifications of concurrency. The products of this effort should be relevant and applicable to the research of many individuals and groups working in the area of expression-oriented multiprocessor systems.

Carnegie Mellon University; Peter Hibbard and Neil S Ostlund; **Performance Evaluation of Multiprocessor Computer Systems**; (MCS-7920698); $61,653; 12 mos.

This project focuses on a multifaceted exploration of the performance characteristics of a fully operational multiprocessor computer system, Cm*. This computer has 50 DEC LSI-11 processors with the potential for expansion up to several thousands of processors, and a novel microprocessor-controlled hierarchical switching structure for accessing memory.

While there has been a reasonable amount of theoretical work on parallel algorithms, very little practical evaluation of applications on asynchronous multiprocessors has been performed. This is primarily due to the small number of operational systems which have a substantial number of processors and the requisite general-purpose software. Cm* provides a unique research opportunity for investigating the actual performance benefits available from multiprocessors when they are applied to important computational problems.

The specific areas of research include implementation of some standard relatively simple, benchmark systems on Cm* including partial differential equations, integer programming and matrix operations, implementation of some algorithms used for real-time graphics displays, investigation and possible implementation of an Integrated Circuit design validation system, and the development and implementation of algorithms for the major steps in molecular orbital calculations in quantum chemistry which are quite complex, and employ many numerical techniques common to other large computational problems. Successful demonstrations of this application on Cm* would be major evidence of the effectiveness of the Cm* architecture for a wide range of scientific calculations.

Rice University; J B Sinclair; **Task Assignment in Distributed Processing Systems**; (MCS-8004107); $55,986; 24 mos.

A distributed processing system consists of a number of processors interconnected by a communication subnetwork. Processors may be heterogeneous, and a task may have its execution distributed among several processors in the system. The cost of the task execution will be a function of both the processor resources required by the execution and the load that the task distribution imposes on the processor interconnection network due to communication between interacting modules of the task.

This research deals with several problems in the area of distributed task executions in loosely coupled distributed processing systems. The overall objective is to learn how to effectively use system resources (CPU and communications subnetwork) in order to minimize task execution costs. Specific problems being studied are: the development of efficient procedures for finding optimal or near optimal task assignments in systems with several processors; the effect of communication subnetwork loading on task execution costs for general classes of interconnection structures; and analysis of specific distributed system organizations which are of practical interest.

University of Washington; Edward D. Lazowska; **Error Minimization in Approximate Analytic Models of Computer Systems**; (MCS-7804347A01); $79,558; 24 mos.

This project focuses on the study of hierarchical analytic models of computer systems. The fundamental scientific issues concern the relationship between the mathematical theory of near-complete decomposability and the science of devising and applying efficient and accurate approximation techniques. Based on an understanding of the theory advanced by Courtois and Vantilborgh and on empirical knowledge of those factors that influence the degree of error arising in approximate solutions based on this theory, the structural characteristics of analytic models that lead to stochastic matrices formally amenable to solution via decomposition are being explored to seek either meaningful error measures or soundly-based guidelines for minimizing error, to translate this understanding into efficient and accurate approximation techniques that exploit available structural information, and to apply these approximation techniques to particular problems. Among these problems are characterizing the performance and behavior of distributed systems, determining the distribution of response times in interactive systems, and identifying performance bottlenecks in software systems during their design.

COMPUTER GRAPHICS

Stanford University; Joseph W. Goodman and Albert Macovski (in collaboration with J. Pearson, Lockheed Palo Alto Research Laboratory); **Industry/University Cooperative Research: Multiplexed Holographic Reconstruction Methods for Three-Dimensional Structures**; (ECS-7926432); $10,094; 12 mos (Joint support with the Automation, Bioengineering & Sensory Systems Program and the Industry/University Cooperative Program - Total Grant $201,869).

> The research addresses the problem of displaying data so that special relationships can be visualized. The research rests on certain recent theoretical developments in the field of computerized tomographic imaging. Methods appropriate to the problem of three-dimensional visualization are being investigated which lead to computer software concepts suitable for implementing in computer algorithms. A particular concept of reprojection is being explored which can be realized in a multiple hologram giving a three-dimensional image. The possible utility of such displays for visualizing spatial relationships is being tested on both data derived from nondestructive testing of metal structures and data derived from medical diagnostic testing.

University of Hawaii-Manoa; Frederick Munchmeyer; **Gauss Contour Aberrations on a Patchwise Polynomial Surface**; (MCS-8003379); $58,259; 24 mos.

> When a surface is constructed with patchwise polynomials for design, interpolation, or approximation, then a contour of Gaussian curvature on that surface will oscillate about its mean contour line. These defects in a patched surface are labeled aberrations.
>
> Similar defects in piecewise polynomial curves are well known; they have been labeled extraneous inflections. Methods are available to reduce or eliminate extraneous inflections in piecewise curves. The principal objective of this research is to develop methods for reducing the aberrations in patchwise polynomial surfaces.
>
> The plan of work is to approximate quadrics, such as ellipsoids, with continuously curving patched surfaces. Gauss curvature contours will be traced on the patches. The aberrations will be displayed and analyzed.
>
> Changes in aberrations will be evaluated in numerical experiments that alter both shape and construction method systematically. The investigation will be restricted to Coons patches. A Coons patch scheme will be sought whose details are optimal in the sense of minimizing Gauss contour aberrations on

quadric shapes. Further, a link will be sought between aberrations and a ratio of patch size to surface shape.

The results of experiments on quadrics will be tested on a torus; if found valid, they will be useful in design, interpolation and approximation.

Cornell University; Donald P. Greenberg; **Development of Computer Graphics Techniques and Applications**; (MCS-7811984A01); $173,988; 12 mos.

This project involves research on advanced computer graphics. The principal focus is on display techniques and input techniques. Under display techniques is included research on hidden surface removal, shadowing, shading, reflectance, texture and pattern systhesis. Research on input techniques includes direct image entry, input methods, extrusion methods, three-dimensional graphic input methods, techniques for surface representation, and conversion methods for generating three-dimensional output from two-dimensional views.

A secondary focus is on color spaces, mappings and scale generation.

SUNY-Stony Brook; Zvi M. Kedem; **Efficient Algorithms and Systems for Computer Graphics**; (MCS-8025376); $40,500; 21 mos.

The general research area deals with the problem of defining a planar-tile approximation to a surface, the information about which is presented as a sample of points lying on it. This problem, beside being of importance in representational computer graphics, has a wide variety of applications in biology, medicine, and design. Under a previous grant, the rather special case where the sample points are given as a sequence of cross-sectional contours with each contour lying on a separate plane was considered.

This research deals with the approximating surfaces for the cases where the data is less structured including the case where there may be several contours lying on one plane, and the case where the sample points are given only as a set without any order.

In the first case, several "generic" types of surfaces as well as several approaches (such as partitioning a plane on which several contours lie into regions based on the distance criteria), which may lead to suboptimal, but good, approximating surfaces are being investigated

In the second case, the main approach being investigated is based on finding the convex hull of the sample points first and then incrementally modifying the surface so that it passes through other sample points.

Ohio State University; Franklin Crow; **Toward More Complicated Computer Imagery**; (MCS-7920977); $75,953; 12 mos.

The realism and utility of computer generated shaded images is severely limited by the meager complexity of the scenes which can currently be handled. In an attempt to improve on this situation, a conventional scan-order hidden surface and display algorithm was extensively modified to enable images of 100 times greater complexity. Experience with these more complex images has reinforced the understanding of how much more complicated truly satisfactory images will have to be.

Hidden-surface algorithms currently in use are limited by sorting steps which require the presence of all data. The data describing scenes are defined inflexibly, making distant views computationally inefficent and closeups lacking in detail. In addition, the production of truly complicated images will require distributing the algorithms over many processors in order to make animated imagery cost effective. These highly interrelated problems are being explored by studying and implementing algorithms designed for concurrent processing environments and oriented to more intelligently defined shape descriptions.

Initial efforts will focus on the design of data structures to support efficient rendition of the same object at many different levels of detail. Subsequent work will focus on algorithms for the display of such objects which are designed for distributed execution. Finally, the algorithms will be implemented and image sequences produced on a multicomputer facility currently being acquired.

Ohio State University; Charles A. Csuri and Richard E. Parent; **Complex Animation and Complex Object Synthesis**; (MCS-7923670); $173,635; 12 mos.

This research concentrates on four tasks dealing with complex motion systems and complex object synthesis. The four research tasks are: complex motion specification and control, surface generation based upon skeleton representation, three-dimensional texture, and points as a graphics primitive.

New algorithms are being developed to mathematically model complex motion systems. As a case study human motion has been selected because it involves parallel processes and it has great dynamic complexity and nonlinearity. Special purpose hardware will be designed and constructed to test these algorithms for real-time display.

An interactive surface generation system is being implemented to create three-dimensional structures from skelton representations.

Algorithms are being developed to simulate visual cues for 3-D surface detail. An attempt will be made to use a portion of the DMAAC (Defense Mapping Agency) data base.

An investigation is being made of points as a graphics primitive. An analysis is being made of the data structure and animation requirements for use in displaying visual results from scientific models.

University of Utah; Richard F Riesenfeld; **Subdivison Algorithms for Curved Surface Representation and Display**; (MCS-8004116); $164,969; 24 mos.

This project is exploring the possibilities and implications of the Oslo Algorithm in Computer Aided Geometric Design (CAGD) and Computer Graphics. This newly proposed algorithm by E. Cohen, T. Lyche, and R. Riesenfeld uses a subdivision scheme based on the theory of discrete splines. Subdivision is an excellent method for computing intersections, general interferences, hidden surfaces and renderings, and other typical geometric attributes like volumes and surface areas.

Until now the models for the surface description and the graphics have had to be separate and therefore cumbersome to use. The algorithm has the potential power to unify these formerly separate modelling areas into one general procedure which generates the appropriate description for either case.

This research is intended to develop the necessary Oslo-type algorithms needed to test the working hypothesis that the Oslo Algorithms is one of the most fruitful and uniformly structured approaches to designing a CAGD system for freeform surfaces.

SOFTWARE ENGINEERING

QUALITY SOFTWARE

Stanford University; George B. Dantzig, Richard W. Cottle, and Walter Murray; **Computer Optimization of Complex Systems**; (MCS-7926009); $105,484; 12 mos.

The Systems Optimization Laboratory (SOL), Department of Operations Research, Stanford University, is a center for research in mathematical programming and its applications. Research activities include both algorithmic development and model development with interaction between them, so as to reduce the gap which normally separates these two areas in practice. The topics of research include:

(1) Efficient methods for large-scale "staircase" and other specially structured linear programs. Of particular interest are the continuous simplex approach, methods based on decomposition, and factorizations designed for staircase matrices.
(2) Several refinements and extensions to the MINOS code for large-scale linearly constrained optimization.
(3) Analysis of several topics in nonlinearly constrained optimization.
(4) A study of Newton-type, sparse quasi Newton, and conjugate gradient methods for large, sparse, unconstrained optimization. It is anticipated that the results in the unconstrained case should suggest useful approaches to the large sub-problems that arise in constrained optimization.
(5) Methods for large, sparse linear least squares, structured quadratic programs, and constrained linear and nonlinear least squares.
(6) Evaluation and comparison of algorithms for various classes of optimization problems.

This work will also include an effort to collect sets of test problems that are non-trivial and representative.

University of CA., Los Angeles; Charles J. Stone; **Statistics and Infinite Particle Systems**; (MCS-8002732); $13,000; 12 mos (Joint support with the Statistics & Probability Program - Total Grant $75,000).

Stone will investigate the asymtotic properties of procedures for nonparametric regression and classification and parametric model selection. Ferguson will work on computational aspects of

Bayes decision rules with respect to priors which are mixtures of Dirichlet priors in certain nonparametric problems. Ylvisaker will work on interval setimates for the parameters of approximately linear models and the adaptation of these estimates to real data. Jennrich will study derivative free statistical algorithms and their application to covariance structure analysis. Liggett will work to develop and apply new monotonicity properties of spin systems, and will study new processes on noncompact spaces. Durrett will study the asymptotic distribution in time, stability of stationary distributions under small perturbations, and phase transitions for certain processes.

Univ. of Cal. Santa Barbara; Webb C. Miller; **Software for Roundoff Analysis**; (MCS-7812288A01); $8,024; 9 mos.

The goal of this research is to produce software which can analyze the propagation of rounding errors in algorithms from numerical linear algebra. Specific areas to be studied are:

(1) Methods for performing error analysis which are not possible with the current software. For instance, it appears possible to analyze cases where, roughly, the effect of rounding error grows with the square of the problem's "condition number".

(2) Techniques for bounding the sensitivity of the conclusions drawn from an error analysis to changes in the model of rounding error propagation.

(3) Techniques for proving that certain computational problems can not be solved by any numerically stable process.

Four techniques developed for roundoff analysis will be used for the automatic generation of test data.

Univ. of Illinois-Urbana; Ahmed H. Sameh; **High Quality Software for Numerical Computation**; (MCS-7918394); $103,500; 24 mos.

The goal of this research is the development of high speed and high quality numerical linear algebra algorithms for parallel and pipeline computers. Such algorithms concern the direct solution of algebraic linear systems of equations, iterative methods for solving large sparse linear systems that arise from the numerical solution of partial differential equations and linear least squares problems. In addition, an automatic error analysis package will be improved so as to perform the various analyses faster and more efficiently. Enhancements will be made to facilitate the detection of possible changes in the computational graphs of algorithms that may improve numerical stability.

University of MD. College Park; Azriel Rosenfeld and Richard Hamlet; **The Development of Transportable Image Processing Software**; (MCS-7718719A02); $37,814; 12 mos (Joint support with the Intelligent Systems Program - Total Grant $75,628).

Under Grant MCS-7718719, techniques have been developed to increase the portability and modularity of package software. The basic idea is to divide the package into pieces, separating out a kernel of routines that interface to each operating system so that it appears identical to the remainder of the package; thus above this interface, all code can be machine-independent. Processing routines are organized into independent modules whose structure makes the system easy to alter or extend.

This project is to develop a transportable image processing software system based on these techniques. The work will be done in collaboration with Prof. R. M. Haralick of Virginia Polytechnic Institute. The system will be written in machine-independent ANSI FORTRAN, and will be interfaced with a number of operating systems on a variety of large- and medium-scale machines.

University of Maryland; James M. Stewart and Robert J. Munn; **The Development of a Generalized Transportable Software Package for the Solution and Refinement of Molecular Structures in Single Crystal Diffraction Techniques**; (CHE-7920201); $19,000; 12 mos (Joint support with the Structural Chemisty and Thermodynamics Program - Total Grant $56,000).

Professors J. M. Stewart and R. L. Munn plan to develop a highly integrated system of generalized computer programs for the analysis of single crystal diffraction data. The developed programs will serve scientists interested in applying single crystal analysis to varied problems in chemistry, geology, biochemistry, mineralory, material science, and related disciplines.

The project will utilize a portable preprocessor in the implementation of the library of programs. The programs developed will be highly transportable, well documented, and optimizable at the user's site. They will be designed to work on "midi" through "maxi" computers either in a batch or, where appropriate, interactive mode.

The crystallographic programs will be designed to treat all types of compounds from simple mineral substances to very high molecular weight compounds such as proteins. They will be general with respect to space group and setting. In addition, the system will form and maintain a data base for each problem under study. Multiple algorithms will be implemented for basic operations where appropriate.

Tufts Univ.; George Cybenko; **The Generation of Random Linear Algebraic Sample Data**; (MCS-8003364); $33,087; 24 mos.

This research will investigate the systematic generation of random sample input data for testing and evaluating mathematical software. Specific attention will be given to identifying and sampling intrinsically defined uniform distributions for classes of linear algebraic objects.

One outcome of this research would be the start of a library of algorithms, akin to existing pseudo-random number generators, for the generation of pseudo-random linear algebraic objects. This would be of immediate value in the testing and empirical evaluation of mathematical software for numerical linear algebraic computations.

All software developed is expected to be efficient, portable, and adaptable to user-supplied pseudo-random number generators.

Univ. of Pennsylvania; Richard M. Heiberger; **Robustness of Algorithms for Regression and Analysis of Variance**; (MCS-7911281); $40,011; 18 mos.

Regression and Analysis of Variance (ANOVA) are two statistical techniques heavily used by researchers in all scientific fields. Both are frequently used in data situations where unambiguous interpretation of their results is not possible. This occurs for ANOVA when there are unobserved cells in the cross-classification or the underlying error distribution is not normal, and for regression when the observed values of some variables are not available for analysis.

This project continues an investigation into the behavior of algorithms when used on data with missing cells or missing values. It is centered on studying the many oft-used, but not well understood, *ad hoc* procedures which have been developed, but whose performance characteristics and operating limits are unknown. New algorithms will be developed as new statistical solutions are derived.

Analysis, Research & Computations, Inc.; John M. Mulvey; **Conference on Testing and Validating Mathematical Programming Algorithms and Software to be Held at the NBS in Boulder, CO. on January 5-6, 1981**; (MCS-8007250); $13,651; 18 mos.

The goal of this conference which is organized by the Committee on Algorithms (COAL) of the Mathematical Programming Society is to focus attention on a variety of issues for which there is little unanimity.

These issues include:

(1) What type of test problems should be used?
(2) How can the structure of real-world examples be introduced into program generators? and

(3) What evaluation criteria should be used and how should these criteria be measured?

Developers and users of optimization software will be present to present their views on these topics.

Virginia Polytechnic Inst.; Robert M. Haralick; **The Development of Transportable Image Processing Software**; (MCS-7927099); $40,350; 18 mos (Joint support with the Intelligent Systems Program - Total Grant $80,700).

Under Grant MCS-7718719 to the University of Maryland, techniques have been developed to increase the portability and modularity of package software. The basic idea is to divide the package into pieces, separating out a kernel of routines that interface to each operating system so that operating system services appear identical to the remainder of the package; thus above this interface, all code can be machine-independent. Processing routines are organized into independent modules whose structure makes the system easy to alter or extend.

The purpose of the project is to develop a transportable image processing software system based on these techniques. The work will be done in collaboration with A. Rosenfeld and R. Hamlet of the University of Maryland. The system will be written in machine-independent ANSI FORTRAN, and will be interfaced with a number of operating systems on a variety of large- and medium-scale machines.

University of Washington; Arthur V Peterson and Richard A. Kronmal; **Efficient Generation of Random Variables From an Arbitrary Probability Distribution**; (MCS-7924382); $45,000; 24 mos (Joint support with the Statistics & Probability Program - Total Grant $71,714).

The objective of this research is to provide a routinely useable source of random variables from any specified distribution. Specifically, a strategy for the efficient implementation of the alias and the alias-rejection-mixture method for arbitrary distributions will be developed. Computer programs to generate the random variable will be programmed and tested.

Washington State Univ.; George Marsaglia; **The Generation and Use of Random Variables in Computers**; (MCS-8005789); $50,000; 24 mos (Joint support with the Statistics and Probability Program - Total Grant $74,933).

This research is concerned with developing new methods and new statistical tests for random number generators, and with new or improved methods for using uniform random variables to produce the kinds of random variables and events required in increasingly precise Monte Carlo studies. New statistical tests are being developed, tests that are more stringent than the standard ones for assessing the suitability of generators, yet realistic, motivated by the needs of increasingly sophisticated users. Results show that the most commonly used generators--congruential and shift-register--do not pass the new tests, but combination generators--those that combine simple standard generators or use one to shuffle the output of another--pass the new tests as well as all the standard tests. Software implementing the new tests and new generators will be made widely available. Software will also be made available for promising new or improved methods for generating many of the discrete and continuous random variables commonly required in Monte Carlo simulations, to supplement or replace current software.

SYMBOLIC AND ALGEBRAIC MANIPULATION

Univ. of Hawaii-Manoa; David R. Stoutemyer; **Scientific Applications of Computer Algebra**; (MCS-7926250); $59,540; 24 mos (Joint support with the Computer Systems Design Program - Total Grant $79,540).

The overall objective of this research is to develop general-purpose applications of computer algebra and to help make computer algebra useful to a larger segment of the scientific community. As one contribution toward these goals, this research concerns development of a program package which infers closed-form analytic solutions from the leading terms of truncated series solutions. As another contribution toward these goals, the research concerns development of a demonstration prototype hand-held computer-algebra calculator.

Univ. of Illinois - Chicago Circle; Vera Pless; **Computer Algorithms in Finite Groups and Combinatorial Structures**; (MCS-7924986); $7,000; 12 mos (Joint support with the Algebra and Number Theory Program - Total Grant $22,000).

This is a continuation of work done previously under MCS-7717272 A01 and is in the areas of combinatorics, computer algorithms, investigations of group theoretic and combinatorial objects on a computer, error-correcting codes, and development of a computer system.

In the area of error-correcting codes, Leon and Pless will complete their investigations of ternary self-dual (24,12) codes. They will compute the mass of the (40,20,8) doubly-even codes -and if the number is reasonable, classify them. Pless will investigate the possible primes which can divide the order of either a doubly-even (72,36,16) or a quaternary (24,12,10) in order to either contruct these codes or eliminate these primes.

Leon will develop and implement algorithms for computing automorphism groups and determining equivalence of block designs and graphs. He will also improve the Schreler-Todd-Coxeter-Sims algorithm for determining the order of permutation group with degree between 100 and 10,000.

Leon and Pless will continue to improve their computer system CAMAC. They are completing a manual and will improve the index, conjugacy class, and relations programs. They are attempting to make CAMAC more accessible to potential users. In addition, they are developing a PL-1 CAMAC which has dynamic storage allocation, structured programs, interruptible command and an editing facility. Much of the research described above uses CAMAC and provides motivation for the types of programs devoloped for the system. The algorithms developed will be implemented in CAMAC.

Kent State University; Paul S. Wang; **Design and Analysis of Computer Algorithms for Polynomial Rational Function Manipulation**; (MCS-7802234A01); $46,153; 24 mos.

This research program consists of the following five topics:

(1) An improved algorithm for polynomial greatest common divisor based on p-adic techniques ;
(2) Using parallel p-adic construction for the partial fraction expansion of rational functions;
(3) Efficient p-adic algorithms for the direct factorization of non-square-free polynomials;
(4) Probabilistic algorithms in symbolic mathematical computation; and,
(5) Integrating the state-of-the-art p-adic algorithms for polynomial and rational function manipulation.

When this research is carried out the frontiers of knowledge related to (1) efficient algorithms for exact symbolic mathematical computation involving polynomials and rational functions and (2) the design and implementation of an efficient software system capable of performing many of these computations should be extended.

University of Utah; Martin L. Griss; **Implementation Strategies for Portable LISP-Based Systems**; (MCS-8007034); $186,477; 24 mos.

This research is the interaction of closely related areas of portable LISP-based and LISP-like symbol manipulation systems, small machine computer algebra systems, and portable small machine software. A predominant goal of this research is the development of a personal computer algebra programming environment for small machines, based on the popular REDUCE computer algebra program. The architectural and implementational issues to be studied are also important for a range of sophisticated personal programming systems. Strategies for implementing a number of portable software systems on a variety of small and medium sized machines will be explored. The programs will include LISP and LISP-like interpreters, a range of computer algebra systems (compatible with existing large machine REDUCE programs), and LISP-based graphics systems, as well as related portable system development software. This work will include the study of portable implementation languages; experimental studies of storage management and evaluation techniques most appropriate to smaller LISP systems; and, study of special evaluator techniques based on hashing, pattern matching, and special hardware support for efficient small machine algebra systems.

SOFTWARE STUDIES & METRICS

University of Connecticut; Edward Balkovich; **The Performance of Decentralized Software**; (MCS-8007466); $36,492; 12 mos.

Many of the objectives used to justify distributed computing can only be achieved by decentralizing both hardware and software. Decentralized software requires interacting, concurrent processes. Their implementation can be costly; however, decentralized software frequently exhibits better performance characteristics than its centralized counterpart due to parallelism. The objectives of this investigation are: (1) to measure the implementation costs for decentralized software using a distributed computer system, and (2) to develop and validate models that explain the performance of decentralized software in terms of implementation costs and software structure. The technical approach will use an existing experimental programming language and distributed computer system to obtain performance measurements for use with probabilistic performance models. The results will help to establish the costs of decentralizing software and the costs of distributing computing. They will also serve to extend existing software engineering methods to include quantitative techniques that are suitable for comparing alternative, concurrent software designs.

Purdue University; Peter J. Denning and James Bouhana (In colaboration with Jeffery Buzen, BGS Systems, Inc.); **Industry/University Cooperative Research: Operational Analysis of Queueing Phenomena**; (MCS-7801729A01 & A02); $80,270; 24 mos (Joint support with the Industry/University Cooperative Program - Total Grant $159,018).

Operational analysis is a newly developed branch of applied mathematics for studying queueing phenomena. For a given computer system in a given observation period (past, present, or future), its objective is a set of relations among operational (i.e., measurable) variables under experimentally testable assumptions. It is different from stochastic analysis, because it does not incorporate unprovable assertions about the causes of the observable behavior of a system. Operational analysis is attempting to reformulate queueing theory as an experimental science. This research continues the development of operational analysis in six areas:

(1) Operational Analysis of finite Markov Chains and recurrent (renewal) processes;
(2) Transient behavior of computer systems;
(3) Operational analysis of "M/G/1" systems;
(4) Approximations of real systems via decomposition;
(5) Error analysis; and
(6) Analysis of software monitor data.

Univ. of MD. College Park; Raymond Yeh; **A Study of Design Methodology in Software and Data Base Systems**; (MCS-7923662); $58,697; 24 mos.

The long term goal of this research is the development of a Software Engineering methodology which will emphasize the separation of concerns for modelling, design and implementation as well as evaluation of all phases of development. This current effort will concentrate on research into conceptual models as an intermediate step between requirement specification and design. The expected advantages of such modelling are: (1) the conceptual model can serve as a means of communication between the user and the designer; (2) the conceptual model can serve as a means to check the consistencies and completeness of the requirements; (3) the conceptual mode can serve as a blue print for evolutionary design; anticipated changes and contingencies can be incorporated into the model.

Univ. of Minnesota; G. Michael Schneider; **An Experimental Investigation of Novice/Expert Behavior in Program Comprehension**; (MCS-8016549); $31,370; 12 mos.

This research project will investigate the cognitive processes that come into play during an attempt to read and understand a program listing. Verbal protocols will be collected from a number of different subjects, and scored and analyzed in order to categorize the strategies and mental operations which are taking place. The questions to be answered are:

1. (1) How is information extracted from the semantic/syntactic construct of a program?
2. (2) How are hypothesis about program behavior proposed and confirmed, and in what order?
3. (3) Are the approaches of novices/experts significantly different? If so, in what way? and
4. (4) Can we propose a general model of the program comprehension process.

Univ. of Missouri Rolla; Kenneth I. Magel; **The Impact of Program Optimization on New Software Development Methodologies**; (MCS-8002667); $33,777; 24 mos.

Program optimization and software development are two areas of Computer Science that have experienced major development recently. The work in each area has progressed largely independently of the other, but the results in each can affect the other. This research will involve the effects of program optimization on the effectiveness of two recent software development methodologies; the Jackson Design method and composite/structured design. The approach will include four phases:

1) analysis of restrictions imposed by the two methodologies on the resulting programs,
2) analysis of the impact of optimization on inverse mapping from an object program to a source program,
3) examination of the operation of a symbolic debugger in the presence of optimization, and
4) study of the interactions of different optimizations.

New Mexico State Univ; J Mack Adams; **A Language Designed for Redundancy**; (MCS-8005106); $73,208; 24 mos.

The goal of this research is to improve software reliability through the inclusion of non-procedural redundancy in the specification of algorithms. The initial phase will involve the design and implementation of a language with coequal procedural and non-procedural aspects. This "bifacial language" will be designed for the convenient expression of an algorithm in two forms. These two forms (procedural and non-procedural) will be quite different, but will complement and audit each other thus providing the redundancy envisioned in this approach. After implementation the language will be applied to a variety of problems to assess its effectiveness.

N. C. State Univ. at Raleigh; William J. Stewart and David F. McAllister; **Near Decomposition and Iterative Approximations for Networks of Queues**; (MCS-8004345); $84,570; 24 mos.

This research involves the study of the errors involved in analyzing a computer system using near complete decomposability. Existing bounds are not only very crude, but often misleading. The goal is to derive much tighter error bounds by extending some recent work of Meyer concerning perturbations of ergodic Markov chains. A second goal is to discover methods for obtaining an optimal decomposition of a system in the sense that the difference in norm between the stationary probability vector of the original chain and the approximation to it is minimized.

PROGRAM TESTING & VERIFICATION

SUNY St. U. Binghamton; Mark Karpovsky; **Detection and Location of Errors in Numerical Computations**; (MCS-8008339); $43,205; 24 mos.

The problems of error detection and/or error correction in the process of computation of numerical functions have become increasingly important. One simple, analytic and unified approach to the solution of these problems has been described. The computation process may be implemented by a computer program or by a specialized digital device. This approach does not depend on the form of representation of input data and on the specific features of the implementation of a program or a device computing the given function. This approach requires for the significant number of important numerical computations (e.g., computation of polynomials) less redundancy than replication approach and less time than check sum approach. The method may be effectively used for quality control acceptance testing of digital devices. In the case of hardware implementation this method may be used also for the testing during installation and maintenance of the corresponding devices.

Univ. Houston Central Campus; Jung-Chang Huang; **Computer Program Testing**; (MCS-8001648); $55,000; 24 mos.

The main objective of this research is to develop effective methods for testing real-time programs. Computer applications that require real-time capabilities include data acquisition, process control, signal processing, and many military command and control functions implemented on the so-called embedded computer systems.

As more and more computers are used in these applications, the need for test methods that can be effectively applied to real-time programs becomes increasingly urgent. However, very little has been done to fulfil this need.

Although a number of test methods have been developed for sequential programs, they can not be directly applied to real-time programs because in general such programs have a cyclic control structure and consist of a number of communicating sequential processes that are to be executed concurrently by one or more processors. Our preliminary investigation shows that the underlying problem may be solved by using the fact that many symbolic traces in such programs are functionally equivalent in the sense that they implement the same set of tasks. The problem becomes more tractable if we need only to test a representative trace from each set of functionally equivalent ones. To use this result, we need to be able to effectively and efficiently identify symbolic traces that are functionally equivalent, to select a test case to exercise a representative trace, and to verify that the representative trace is indeed exercised during the test. These are the key problems that we shall study in this research.

Univ. of Texas at Dallas; Joe Duran; **A Study of Program Testing and Software Reliability Estimation**; (MCS-8003322); $94,865; 24 mos.

Program testing is the most widely used method for establishing software validity. It has high cost and cannot guarantee correctness. This project involves investigations into improving the cost effectiveness of testing and developing methods for rigorously inferring the degree of program validity from test results. This project covers: (1) experimentation and analysis to investigate the cost effectiveness of segment, branch, path and random testing; (2) investigations on improving segment, branch, and path testing methods through the study of a subsuming strategy called required element testing; (3) extension of validity inference methods, paying particular attention to operational reliablility measures.

SOFTWARE TOOLS AND PROGRAMMING ENVIRONMENTS

University of Arizona; Ralph E. Griswold; **Formalizing and Automating the Implementation of Portable Software**; (MCS-7802545A01); $166,216; 24 mos.

The project involves research and development of mechanisms for the systematic generation and explication of portable software.

Research to date has concentrated on experimental work and the development of linguistic formalisms for describing software installation. Specific projects include design and implementation of a portable peephole optimizer, development of portable systems software, experiments in porting real software systems, and the formulation of command languages and programming languages for describing the installation of software.

Future research is directed toward generalization, integration and validation of the individual ideas and projects. The projects share a common source. They are the tools from daily programming experience that research has not made portable: optimizing, compilers, linkers/loaders, file systems and command languages.

Univ. of California - Santa Barbara; Webb C. Miller; **TOOLPACK at University of California - Santa Barbara**; (MCS-7926441); $55,090; 12 mos.

TOOLPACK is a systematized collection of software tools to facilitate the development and maintenance of FORTRAN programs. The collection will be a mechanism to promote the use of high quality tools in software engineering research and in the development of numerical software. The project is a collaborative effort between universities, government and industry. The cooperating organizations are Argonne National Laboratories, Bell Laboratories, International Mathematical and Statistical Libraries, Inc. (IMSL), Jet Propulsion Laboratory, Numerical Algorithms Group (NAG), Purdue University, University of California, Santa Barbara and the University of Colorado.

Univ. of Southern California; Robert M. Balzer and David Wile; **Supervisory Control of Transformational Implementation Systems**; (MCS-7918792); $100,527; 12 mos (Joint support with the Software Systems Science Program - Total Grant $201,054).

This project is aimed at the long-term development of Transformational Implementation Systems. The work falls into two categories, systems building and fundamental research. The systems building activity provides essential support as a means of building an experience base for developing the insights and perceptions which guide the research and as an experimental vehicle for testing ideas and hypotheses.

The ultimate system is presently seen as having five sets of facilities:

(a) facilities to impose a structure on transformation selection and application, involving planning subsystems, documentation subsystems and maintenance subsystems.

(b) facilities to prove applicability criteria of properties of transformations. Transformations may be applied before some properties are proved applicable necessitating subsequent proof of such properties by inference or symbolic execution or via a general purpose theorem prover or a special purpose property prover.

(c) facilities to do automatic program simplification and to provide automatic application of low level transformations that seek canonical forms.

(d) facilities for combining individual transformations into layer coordinated packages.

(e) facilities to generate new transformations for the catalog on the basis of interactive user editing of the state of the program being generated.

Univ. Colorado at Boulder; Leon Osterweil; **Toolpack: University Of Colorado Participation**; (MCS-8000017); $83,220; 12 mos.

TOOLPACK is a systematized collection of software tools to facilitate the development and maintenance of FORTRAN programs. The collection will be a mechanism to promote the use of high quality tools in software engineering research and in the development of numerical software. The project is a collaborative effort between universities, government and industry. The cooperating organizations are Argonne National Laboratories, Bell Laboratories, International Mathematical and Statistical Libraries, Inc. (IMSL), Jet Propulsion Laboratory, Numerical Algorithms Group (NAG), Purdue University, University of California, Santa Barbara and the University of Colorado.

Yale University; Alan J. Perlis; **Workshop on Programming Environments, Ridgefield, Connecticut, June 1980**; (ECS-8012477); $5,000; 6 mos (Joint support with the Computer Engineering Program - Total Grant $10,000).

The term "Programming Environments" refers to the rather elaborate set of tools available to computer programmers working in an interactive environment. Such tools include, text editors, compilers, interpreters, debuggers and recently, editors that are sensitive to the syntax of the language, special printing programs that reformat a program to increase readability, and file systems that coordinate all of the files that make up a single program. In order to facilitate communication among researchers in this field, and to promote interaction between developers and intended users, a Workshop on Programming Environments is being held on June 2-4, 1980. Some of the important research issues being explored are:

Can programming environments be defined to support particular programming methodologies (e.g., stepwise refinement)? What are the relationships between programming environments and programming language design? Can environments be built in a portable way, relatively independent, of a particular machine, of particular terminal characteristics, or even of a target language? Is it possible to develop a language-independent generator of language-dependent enviroments? Is there evidence that programming enviroments can significantly increase programmer productivity?

University of Connecticut; John R. White; **Computer Assisted Software Evolution**; (MCS-8005113); $69,473; 24 mos.

Producing high quality complex software systems with reasonable life-cycle costs has, and continues to be, a major problem. This research is directed at the problem of high software costs. The approach, however, will be to focus on the costs associated with the post-development (maintenance) phase of the software life-cycle. The specific objective of the research is to reduce the cost associated with the evolution of well-structured, complex systems. The approach to be followed centers on the formulation of a software maintenance knowledge-base around which tools can be developed to assist in comprehending a system's organization. A clear understanding of the structural, functional, and performance characteristics of a system is essential before evolutionary changes can be made. Successful completion of the research will contribute to a better understanding of how to support the evolution of systems in response to changing requirements. This support will not only contribute to a reduction in total maintenance costs but will help extend the useful lifetime of complex systems. Software longevity is the key issue in bringing life-cycle costs under control.

Purdue University; John R. Rice; **Template Processors and Toolpack Evaluation**; (MCS-7926310); $39,895; 12 mos.

TOOLPACK is a systematized collection of software tools to facilitate the development and maintenance of FORTRAN programs. The collection will be a mechanism to promote the use of high quality tools in software engineering research and in the development of numerical software. The project is a collaborative effort between universities, government and industry. The cooperating organizations are Argonne National Laboratories, Bell Laboratories, International Mathematical and Statistical Libraries, Inc. (IMSL), Jet Propulsion Laboratory, Numerical Algorithms Group (NAG), Purdue University, University of California, Santa Barbara and the University of Colorado.

Massachusetts Institute of Technology; Roy Kaplow; **New Interactive Computer-Use Strategies Based on the Enhanced-Input Terminal System**; (MCS-7804755A01); $50,000; 12 mos(Joint support with the Special Projects Program - Total Grant $102,050).

A new type of computer terminal has been developed with enhanced capabilities for user input, including: user-defined, potentially unlimited symbol set; user-defined, free-format, touch-activated keyboards; and dynamically changing, software and user-controlled keyboard presentations which follow task progression. The terminal is based on graphical display device on which any keyboard design can be displayed instantaneously. This project will extend and examine the reach of this new environment for computer interaction through a two-faceted project. First, it will establish broad, affordable and more varied access through distribution over an existing two-way cable-TV network, and second, it will explore the impact of this new user/computer/video interface through study of usage patterns and through research on new languages and language concepts which the system makes feasible.

Such interfaces may have significant impact on the use of computers by non-experts, and by persons with mental or physical disabilities.

Mass. Inst. of Technology; Gerald J. Sussman and Carl E. Hewitt; **Computer Aided Evolutionary Design for Software Engineering**; (MCS-7912179); $50,000; 12 mos (Joint support with the Intelligent Systems Program - Total Grant $100,000).

Large software systems are generally associated with high cost and low reliability. These problems are not due primarily to sloppy programming or poor management, but rather are symptoms of the lack of technology for aiding software engineers in the process of evolutionary design. The fundamental issues involved in constructing an interactive computer aided design tool for software engineering will be investigated. The principles developed in this research should be applicable to the construction of similar aids for other engineering disciplines. Automatic program verification techniques now available form only part of the methodology necessary to provide powerful assistance to the designers and implementers of large systems. Verfication techniques are most suitable for proving the correctness of algorithms. The complexity and evolutionary nature of software systems requires a number of additional techniques.

The evolutionary nature of large systems is partiallly due to the fact that simplifying assumptions must be made in order to come up with an initially feasible design. Unfortunately, such "first order" designs need to be debugged when the simplifying assumptions are relaxed. This calls for design aid techniques which deal effectively with changing and incomplete specifications.

The managing of complexity is a fundamental issue in all engineering disciplines. Identified are three major techniques used in more mature engineering fields such as electrical and mechanical engineering which seem applicable to the engineering of software systems, incremental modelling, multiple and almost hierachical decompostion, and analysis by inspection.

University of Massachusetts - Amherst; Henry F. Ledgard; **Human Factors in Interactive Languages and Systems**; (MCS-7680854A03); $9,900; 12 mos.

This research involves a study of design principles for interactive systems with primary emphasis on the human factor. In particular, command languages, system responses, editors, and other user aids will be studied in the effort to make interactive systems pleasant and productive to use. To promote careful design and standarization definition mechanisms for interactive systems will be developed. The effort will be based on known results in human performance.

Cornell University; Richard W. Conway; **Diagnostic Facilities and Interactive Program Development Systems**; (MCS-8003304); $80,519; 12 mos.

One of the goals of this research is the development of a program development system by the adaptation of the error-repair philosophy of the PL/CS system to an interactive environment. Since the Program Synthesizer, which was also developed at Cornell University, has a different internal structure and presents a different interface to the user, there will be an excellent opportunity to compare the two approaches. Error-repairing processors have been in use for several years but there has never been any serious evaluation of their performance. Another goal of this project is to perform an experimental evaluation of error-tolerant methods of program development.

Cornell University; Ray Teitelbaum; **Syntax-Directed Programming Environments**; (MCS-8004218); $145,033; 24 mos.

This project involves the design and implementation of a highly interactive environment for computer programming, called the Cornell Program Synthesizer. The Synthesizer is a self-contained programming environment with integrated facilities to edit, file, execute and debug programs. One part of the project is to design and implement a editor-complier for generating program editors.

INTELLIGENT SYSTEMS

THEORIES OF PATTERN ANALYSIS, SYNTHESIS, AND RECOGNITION BY COMPUTER

SRI International; Harry G. Barrow and Jay M.Tenenbaum; Recovering Intrinsic Scene Characteristics From Images; (MCS-7901830A01); $101,553; 12 mos.

This research will explore and develop computational theory of vision. The theory asserts that the early stages of human (and machine) vision consist of describing a scene in terms of intrinsic characteristics such as the orientation, and reflectance of the surfaces within the scene, as well as the illumination incident upon them. The theory is supported by three types of evidence: the utility of such intrinsic characteristics for higher-level scene analysis, the apparent ability of humans to describe these characteristics over a wide range of viewing conditions, and a theoretical argument that the intrinstic characteristics are mathematically derivable from the scene by a noncognitive and nonpurposive process. Extraction of the intrinsic scene characteristics depends on exploiting constraints derived from assumptions about the nature of the scene and the physics of the imaging process.

Univ. of Cal.-Los Angeles; Judea Pearl; An Investigation of the Role of Representations in Problem Solving; (MCS-7807468A02); $56,058; 12 mos.

The primary objective of this research is to understand the tradeoff between various ways of representing knowledge in a computer and to understand the means by which mechanical shifts in representation can improve problem-solving performance. This program involves three interrelated tasks:

(1) Analytical studies to determine conditions under which a particular problem domain would lend itself to a beneficial shift in representation,

(2) Expand the capabilities of a knowledge acquisition system designed to elicit information about inexact relationships among issues, conditions and actions,

(3) Develop a computational model of imagery reasoning, simulating the transformation between verbal (left hemispherical) and visual (right hemispherical) modes of human reasoning. Investigate whether similar

transformation could be beneficially employed in computer systems.

Indiana Univ-Bloomington; Douglas R Hofstadter; **Seek-Whence: A Project In Pattern Understanding**; (MCS-8009201); $39,045; 12 mos.

SEEK-WHENCE is a research project in artificial intelligence, whose target is the mechanization of the processes involved in the detection of patterns in sequences, the discovery of the rules underlying those patterns, and the generalization of those rules to produce related sequences such as those to which people generalize the original sequence.

University of Michigan; Arthur W. Burks and John H. Holland; **Formal and Interdisciplinary Studies of Adaptive and Computing Systems 1979-1982**; (MCS-7826016A01); $66,909; 12 mos (Joint support with the History and Philosophy of Science Program - Total Grant $76,909).

The Logic of Computers Group at the University of Michigan is engaged in the development of logical formalisms applicable to digital computing systems and to computer investigations of natural systems. These studies range through switching theory, deterministic automata, probabilistic logics, the formal theory of evolutionary and adaptive systems, and the analysis of complex dynamic systems with multiple feedback loops. These systems occur in engineering, economics, biology, ecology, psychology and anthropology, and are not amenable to standard analytic techniques. The current work will emphasize development and application of adaptive systems and genetic algorithms, and continuation of research in the history of computation.

University of Michigan; John H. Holland; **An Interdisciplinary Workshop in Adaptive Systems to be Held at the University of Michigan on July 21-23, 1980**; (MCS-8002446); $6,800; 7 mos.

The objectives of the Interdisciplinary Workshop in Adaptive Systems are: (1) to provide an opportunity for researchers directly involved in this area to meet and discuss current results and algorithms, (2) to facilitate dissemination and interchange of ideas concerning genetic optimization algorithms among prominent researchers working in related areas.

Oregon State University; Kennan T. Smith; **Mathematical Aspects of Divergent Beam Radiography**; (MCS-7900330A01); $10,000; 12 mos (Joint support with the Applied Mathematics Program and the Integrated Basic Research Group - Total Grant $34,005).

The investigator's program concerns the mathematical theory of radiography. The investigator is interested in the nature of the total information conveyed by X-rays from many sources, the extent to which this information determines the object x-rayed, suitable configurations of sources, and methods for using X-ray data to build a detailed reconstruction of the object.

Carnegie Mellon Univ; Kendall J Preston; **N-Dimensional Cellular Logic**; (MCS-8000666); $67,891; 20 mos.

Cellular logic is Boolean algebra performed on arrays of logical numbers. Such arrays are frequently generated from thresholding arrays of real numbers, e.g., as in image processing. The cellular logic operator (CLO) is the multivariate logical function which is used to transform the set of logical values of points in an array into a new set of values. The present value of each point in the array along with the values of its neighbors are taken as the independent variables. The dependent variable is the number assigned to the new value of each point. Sequences of CLO's have been developed to extract spatial features in image analysis. To date almost all studies in this field have been in 2-space. This research project aims to discover the fundamentals of CLOs and CLO sequences in spaces of 3 and higher dimensions. Parameters such as the crossing number which are useful in 2-space have no direct meaning in these dimensions. Thus new generalizations of these parameters will be developed and tested. The work is relavent to (1) the development of 3D image sensors and (2) the needs for cluster analysis of N-dimensional data.

Brown University; Ulf Grenander and Walter Freiberger; **A Theory Of Patterns And Its Applications**; (MCS-7924983); $98,724; 12 mos.

This research is directed toward extending and completing the mathematical theory of regular structures (pattern theory) and applying this theory to specific problems in physics and biology. Application areas to be considered include:

- -- the structure of scientific inference
- -- computer tomography
- -- image restoration
- -- biological growth models
- -- morphogenesis
- -- mathematical semantics
- -- social domination patterns
- -- neural networks.

Virginia Poly. Inst.; Robert M. Haralick; **Analysis of Scenes Using Two-Dimensional Shape Information**; (MCS-7923827A02); $30,909; 12 mos.

The long-range objective of this research is automated recognition of known objects in images, in the presence of distortions introduced by changes in perspective, orientation, and scale. The effort will proceed through three phases:

1. Automatic segmentation of images into meaningful regions, based in part on edge and texture analysis
2. Automatic descriptions of region shapes, using new graph-theoretic clustering techniques
3. Automatic matching of regions to known three-dimensional objects, based on analysis of region and object shapes.

Virginia Polytechnic Inst.; Linda G. Shapiro; **Analysis of Scenes Using Two-Dimensional Shape Information**; (MCS-7919741A01); $41,603; 12 mos.

The long-range objective of this research is automated recognition of known objects in images, in the presence of distortions introduced by changes in perspective, orientation, and scale. The effort will proceed through three phases:

1. Automatic segmentation of images into meaningful regions, based in part on edge and texture analysis
2. Automatic descriptions of region shapes, using new graph-theoretic clustering techniques
3. Automatic matching of regions to known three-dimensional objects, based on analysis of region and object shapes.

MECHANIZATION OF PERCEPTION AND LANGUAGES

Stanford University; John Chowning (in collaboration with Cordell Green, Systems Control Inc.); **Industry/University Cooperative Research: Intelligent Systems for the Analysis of Digitized Acoustic Signals**; (MCS-8012476); $12,979; 12 mos (Joint support with the Industry/University Cooperative Program - Total Grant $86,527).

The objective is to undertake research in developing methods and techniques for analyzing and understanding digitized acoustic signals. The goal will be to more formally characterize the nature and characteristics of acoustic signals and to explore the use of artificial intelligence and signal processing techniques in accomplishing and partially automating the task of this analysis.

The approach will be .to develop a knowledge-based signal understanding system that will input a digitized sequence of acoustic signals. The system will produce a characterization of the sound in the form of a "map" -- a representation of the sound that involves not only an indication of the acoustical elements and processes presented, but will also provide information about timing, source identification, pitch and loudness features, and complex signal stratification.

Systems Control Incorporated; Cordell Green (in collaboration with John Chowning, Stanford University); **Industry/University Cooperative Research: Intelligent Systems for the Analysis of Digitized Acoustic Signals**; (MCS-7923282); $13,766; 12 mos (Joint support with the Industry/University Cooperative Program - Total Grant $91,779).

The objective is to undertake research in developing methods and techniques for analyzing and understanding digitized acoustic signals. The goal will be to more formally characterize the nature and characteristics of acoustic signals and to explore the use of artificial intelligence and signal processing techniques in accomplishing and partially automating the task of this analysis. The approach will be to develop a knowledge-based signal understanding system that will input a digitized sequence of acoustic signals. The system will produce a characterization of the sound in the form of a 'map' -- a representation of the sound that involves not only an indication of the acoustical elements and processes presented, but will also provide information about timing, source identification, pitch and loudness features, and complex signal stratification.

Purdue University; King-Sun Fu; **Parallel Algorithms and Computer Architectures for Image Processing and Pattern Recognition**; (MCS-7818906A01); $3,942; 12 mos.

This research extends pattern recognition theory into a significant problem area: the characterization of biological tissue textures and histologic patterns. Graph theory and statistical pattern recognition will be the mathematical basis for the representation and recognition of tissue macrotexture. Chromation and granularity patterns of tissues will be treated as stochastic spatial processes , to be compared and analyzed statistically.

Purdue University; Kai Hwang and King-Sun Fu; **Parallel Algorithms and Computer Architectures for Image Processing and Pattern Recognition**; (MCS-7818906A02); $105,811; 12 mos.

The long-range objective of this research is to derive general relationships between representative classes of image processing and pattern recognition algorithms, and alternative computer architectures for implementing them. Two general types of algorithms will be investigated: (1) real and generalized solutions of large linear systems, 92) parsing algorithms for picture description languages. Two general architecture concepts will be studied: (1) dynamically reconfigurable multiprocessor systems, (2) associative processors, pipelined computers, SIMD and MIMD machines.

Purdue University; Leah J. Siegel and Howard Jay Siegel; **Parallelism in Speech Processing**; (ECS-7909016); $40,481; 24 mos (Joint support with the Computer Engineering Program - Total Grant $80,981).

The objective of this research program is to study the parallelism in speech processing tasks and how this parallelism can be exploited by large-scale multiprocessor systems. Both parallelism within a task and parallelism among tasks are being investigated for a variety of specific important speech processing problems. Machine independent lower and upper time bounds, using a model of a partitionable multi-microprocessor system as a framework for the analyses are being derived. These algorithms are based mainly on the SIMD (single instruction stream - multiple data stream) and multiple - SIMD modes of parallelism. A set of time complexity equations for evaluating the execution of a set of tasks on a partitioned system in terms of parameters such as the number of partitions, the size of the partitions, the time for intra- and inter-partition communications and instruction speed are also being derived. This research promises to advance the state-of-the-art of both parallel processing and speech processing.

Univ. of Md. College Park; Azriel Rosenfeld and Dianne P. O'Leary; **Representation and Control in Computer Vision: Multilevel Relaxation Approaches**; (MCS-7923422); $100,012; 12 mos (Joint support with the Automation, Bioengineering, & Sensory Systems Program - Total Grant $130,012).

Computer vision can be regarded as a process of establishing a correspondence between specific relational information derived from a scene and general relational information defining a model for a class of scenes. Computer vision systems make use of three types of data structures--arrays, region or object representations, and relational structures. In analyzing a given scene, information is discarded when passing from one representation to another. Multiple-resolution representations such as "pyramids" will be used to make this process more selective. They will also provide new ways of modeling shape and geometry, and of introducing information about them into the array-level processing.

The process of finding correspondences involves a potentially combinatorial search. Many "smart" search techniques exist, but parallelism provides the best possibility for speedup. "Relaxation" methods iteratively apply local constraints in parallel to reduce the size of the search space. Experiments on a variety of problems have shown that these methods are robust. A Bayesian basis for relaxation has recently been developed. Relaxation methods are being successfully extended to multiple, multilevel processes. The conditions under which these relaxation methods work are more fully understood as a result of these investigations.

University of MD. College Park; Azriel Rosenfeld and Richard Hamlet; **The Development of Transportable Image Processing Software**; (MCS-7718719A02); $37,814; 18 mos (Joint support with the Software Engineering Program - Total Grant $75,628).

Under Grant MCS-7718719, techniques have been developed to increase the portability and modularity of package software. The basic idea is to divide the package into pieces, separating out a kernel of routines that interface to each operating system so that it appears identical to the remainder of the package; thus above this interface, all code can be machine-independent. Processing routines are organized into independent modules whose structure makes the system easy to alter or extend.

This project is to develop a transportable image processing software system based on these techniques. The work will be done in collaboration with Prof. R. M. Haralick of Virginia Polytechnic Institute. The system will be written in machine-independent ANSI FORTRAN, and will be interfaced with a number of operating systems on a variety of large- and medium-scale machines.

Mass. Inst. of Tech.; Whitman A. Richards; **Natural Computation and Control**; (MCS-7923110); $184,196; 12 mos (Joint support with the Division of Information Science & Technology - Total Grant $234,196).

Research in natural computation explores the information processing mechanisms utilized by biological systems in performing basic sensory and motor functions. The MIT effort is primarily concerned with understanding the computational mechanisms which underlie the human visual system's representations of the external world. Topics to be investigated will include: (1) stereopsis, (2) texture, (3) structure from motion , (4) transparency, (5) color perception and normalization, and (6) derivation of object shape from contour and shading.

Univ. of Mass. Amherst; Edward M. Riseman; **A Computer System for Visual Interpretation of Natural Scenes**; (MCS-7918209A01); $124,600; 12 mos.

The long-range objective of this research is to automate the analysis and interpretation of imagery. The approach is to incorporate a-priori knowledge about the environment into a computer system (VISIONS) which combines the high-level priori knowledge with low-level scene segmentation algorithms, and produces analyses and descriptions of the objects in the scene. The use of perspective, 2D and 3D schemas are part of the primary research thrust.

Michigan State University; Carl V. Page; **A Study of Augmented Relaxation Labeling for Parallel Image Understanding**; (MCS-8004126); $40,066; 12 mos.

The theoretical concept of augmented relaxation process has been defined with the aid of practitioners of image understanding. A recent Ph.D. thesis has extended this definition. Theoretical consequences of this definition will be studied with an eye to the development of parallel algorithms for image understanding. In particular, controlled processes which coordinate the interaction of global and local information will be studied by means of stochastic automata and stochastic languages. Key questions concern the generality of the methods, their stability and how amenable they are to parallel processing. A few experiments will be run on well-understood data to sharpen the definitions and verify results. A novel aspect of this work is that both top-down knowledge and bottom-up knowledge interact via a probability distribution over image descriptors.

Mississippi State Univ.; Lois C. Boggess; **Prepositions as Spatial Operators: A Natural Language Visual Analog and Inferencing System**; (MCS-8004885); $23,929; 12 mos.

The research is on the cognition of spatial concepts underlying natural language use of prepositions. Focus is on a broad, comprehensive model producing a set of primitives to handle non-idiomatic uses of the locative prepositions; it seems reasonable to assume that such primitives would encompass many of our most fundamental notions of space. The model is designed to accept natural language text descriptions of scenes and produce a three-dimensional model (comparable to a mental image) of the scene. It then responds to questions about the spatial relations, both explicit and implicit, between the objects in the scene. Since the model is required to make judgments, research questions raised in this latter portion of the model necessarily address the problem of appropriateness of vocabulary choice as opposed to strict, canonical interpretation of a given text.

New York University; Ralph Grishman; **Natural Language Interfaces Using Limited Semantic Information**; (MCS-8002453); $63,500; 12 mos.

Natural language interfaces to computer systems offer the potential for directly processing the information in technical and scientific texts and for making computer systems readily accessible to a much wider group of users. A major problem in designing a compact, portable natural language interface has been the need to incorporate sufficient background information to permit the correct analysis of sentences in a particular domain. For many domains, it is not practical to collect all the information known to a potential user. This raises the question: is there a small subset of domain-specific information adequate for analyzing a sufficient fraction of the sentences to make the inferface usable? This research project will investigate one possible subset, a description of the structure of the information in a domain. This description, called a domain information schema, consists primarily of a classification of the objects in the domain and the possible relations between these objects. The adequacy of the domain information schema as a source of domain-specific knowledge will be tested on two existing natural language interfaces. This will require several extensions to current techniques in computational linguistics in order to maximize the use of the domain information schema. The interfaces will be applied to substantial texts, specifically medical records and corresponding queries; the success and failures of the interfaces will then be analyzed to assess the adequacy of the proposed domain information schema.

SUNY St. U. Buffalo; Stuart C. Shapiro; **Studies of Deductive Networks for the Representation of Knowledge**; (MCS-8006314); $50,000; 12 mos.

Research will be conducted on the use of "monitors" (master processes which control the scheduling of other communicating processes) which have recently been developed for controlling and keeping track of subdeductions. We will investigate their use in determining when a successful subdeduction has no more results to report, in suspending an entire subdeduction when it is no longer needed, and in resuming a suspended subdeduction when it becomes useful for another deduction. We will investigate a way of representing a natural deduction system based on indexing each proposition with the set of initial assumptions it depends on. This method promises to liberate the notion of "contexts" from the hierarchical order of development it usually requires. We will investigate a method of combining the modes of reasoning forward from new data and backward from questions in a consistent and cooperative way which depends not on how rules are stored, but on how resources are allocated during read time and question time. We will continue our investigations into reasoning by the exception principle, and on the relative strengths of path-based and node-based reasoning.

University of Rochester; James R. Low and Jerome Feldman; **Advanced Compiling and Distributed Computing**; (MCS-7902971A01); $66,785; 12 mos (Joint support with the Software Systems Science Program - Total Grant $133,570).

The goal of this project is to increase our understanding of the problems of "intelligent compiling" in which is to be included not only traditional optimization techniques, but also use of heuristic techniques from artificial intelligence to choose algorithms and data structures, and generally improve programs written in a high-level language. A particular area of concern is the programming and validation of loosely-coupled systems such as those that arise in distributed computing.

Carnegie Mellon Univ.; Raj Reddy; **Knowledge Acquisition and Learning in Speech Understanding**; (MCS-7825824A01); $116,093; 12 mos.

Speech understanding involves complex tasks in signal learning and symbol learning. This research is directed toward discovering computer-based techniques for knowledge acquisition and learning, to deal with the following problems in speech understanding by machine: (1) new environments, (2) new speakers, (3) new words and grammatical constructs, and (4) new task domains.

University of Pensylvania; Ruzena K. Bajcsy, Aravind K. Joshi, and Norman Badler; **Scene Understanding**; (MCS-7807466A02); $67,271; 12 mos (Joint support with the Automation, Bioengineering, & Sensory Systems Program - Total Grant $134,541).

The long-range objective of this research is to determine a combination of visual and linguistic mechanisms which will enable an intelligent system to:

(1) recognize three-dimensional objects, given sequences of two dimensional images taken from a moving platform,
(2) represent and store in memory its knowledge and perceptions of these objects, and
(3) translate this knowledge into natural language for communication to humans.

This project represents the fusion and continuation of two previous research efforts on analysis and graphical display of moving objects and computer analysis of outdoor scenes.

Univ. of Pennsylvania; Aravind K. Joshi; **Research in Natural Language Processing**; (MCS-7808401A02); $116,040; 12 mos.

The long-range goal of this research is the development of computer systems that use natural language to perform some tasks which currently require intelligent human intervention. The focus is on data-base interrogation and on the specific problems which cause the computer to fail to understand or respond cooperatively to ostensibly reasonable questions or commands. The following key features of conversational behaviour are being analyzed:

(1) cooperative responses to questions in data base domains,
(2) techniques for basing inferences on incomplete information, and
(3) the structures and functions of descriptions.

Results are to be validated on a practical data base (computer utilization, by project, at a large research facility.)

Virginia Polytechnic Inst.; Robert M. Haralick; **The Development of Transportable Image Processing Software**; (MCS-7927099); $40,350; 18 mos (Joint support with the Software Engineering Program - Total Grant $80,700).

Under Grant MCS-7718719 to the University of Maryland, techniques have been developed to increase the portability and modularity of package software. The basic idea is to divide the package into pieces, separating out a kernel of routines that interface to each operating system so that operating system services appear identical to the remainder of the package; thus above this interface, all code can be machine-independent. Processing routines are organized into independent modules whose structure makes the system easy to alter or extend.

The purpose of the project is to develop a transportable image processing software system based on these techniques. The work will be done in collaboration with A. Rosenfeld and R. Hamlet of the University of Maryland. The system will be written in machine-independent ANSI FORTRAN, and will be interfaced with a number of operating systems on a variety of large- and medium-scale machines.

Univ. of Wisconsin-Madison; William S. Havens; **Applying Recursive Cue/Model Hierarchies To Schemata Based Computer Vision**; (MCS-8004882); $23,572; 12 mos.

A major problem in model-driven vision systems is the invocation of appropriate models to interpret a given image. Typically, data-driven methods are employed to generate low-level image cues to select likely models as hypotheses. It has been pointed out that this method is ineffective. Low-level cues are highly ambiguous; matching to many inappropriate high-level models.

As a solution to this problem, we propose to integrate model-driven and data-driven recognition in schemata representations by employing a recursive hierarchy of cues and models. Schema models are invoked both by primitive cues computed directly from the image and by abstract cues created recursively as the result of recognition. The successful recognition of a schema instance at one level in the hierarchy yields a context-sensitive cue to invoke schema models at higher levels.

These methods will be applied to understanding hand-drawn sketch maps and to automatically classifying urban aerial photography. This second application should be of significant assistance to remote sensing research in the automatic prediction of urban pollution from sediment run-off.

MECHANIZATION OF KNOWLEDGE AND INFERENCE

Rand Corporation; Donald A. Waterman; **Workshop on Expert Systems - Los Angeles, CA**; (MCS-7926532); $12,984; 12 mos (Joint support with the Integrated Basic Research Group - Total Grant $22,984).

In the past decade a number of computer programs have been developed which apply the domain-specific knowledge of human experts to problems in molecular structure determination (MOLGEN), advise physicians in antimicrobial therapy (MYCIN), and aid geologists in evaluating mineral sites (PROSPECTOR). The purpose of this workshop is to study basic computer science issues that arise in the theory and computer implementation of these "expert systems".

Stanford University; Bruce G. Buchanan; **Knowledge-Based Consultation Systems**; (MCS-7903753A01); $64,130; 12 mos.

Rule-based systems are emerging as one of the most productive areas of research and application of intelligent systems. The goal of this research is to abstract the most useful features from existing domain-specific rule-based systems such as DENDRAL or MYCIN, and to incorporate these principles into a generalized or domain-independent system, EMYCIN, which can be readily specialized for particular applications.

Stanford University; Edward A. Feigenbaum; **The Automation of Scientific Inference: Heuristic Computing Applied to Protein Crytallography**; (MCS-7923666); $54,469; 24 mos.

The objective of this research is to determine the range of applicability of heuristic programming to the determination of protein molecular structures from x-ray crystallographic data. The principal research areas are:

- to incorporate the formal and informal knowledge which expert protein crystallographers use in inferring protein structure, into a system of machine-interpretable rules,
- to explore alternative program organizations and knowledge representations which will allow various knowledge sources to interact cooperatively,
- to design and implement an intelligent computer system for generating protein structural models from the x-ray data.

Stanford University; John McCarthy; **Basic Research in Artificial Intelligence**; (MCS-7800524A02); $110,238; 12 mos.

Philosophy should include the study of the relations between world structures and systems within them that seek knowledge. The present research is motivated by the problem of designing an artificial intelligence system and is based on the idea that the study of artificial intelligence can be separated into epistemology and heuristics. Epistemology is concerned with determining what facts and inference rules are pertinent to a problem and how to represent these facts and rules in machine memory. Heuristics is concerned with procedures for deciding what action to take, based on the pertinent facts.

One goal of this research is to identify and describe precisely the intellectual mechanisms required for problem solving. New machine-compatible techniques for applying the processes of induction, deduction, and conjecture to a data base, will be investigated.

Stanford University; John McCarthy; **The Mechanization of Formal Reasoning**; (MCS-7905998A01); $96,013; 12 mos.

The objective of this project is to develop a common representational formalism and deductive system for mechanizing a variety of tasks invovling reasoning. The approach is based on the FOL system developed by Dr. Richard Weyhrauch at the Stanford A.I. Laboratory. The researchers will address such diverse problems as: reasoning about actions, beliefs, and knowledge; perception and control of actions; and verification of hardware designs by a formal proof method. The investigation will include an examination of conditions under which reasoning at a meta-level provides more efficient solutions to problems than reasoning at the object-level.

Stanford University; Patrick Suppes; **Interactive Theorem Proving**; (MCS-8011975); $85,295; 12 mos.

This project requests funds for research on mechanical theorem-proving in EXCHECK--a goal-structured, interactive, proof-checking system used to teach logic and set theory to approximately 300 students each year at Stanford University. Our major goal is to shift the emphasis of the EXCHECK system from a primarily logical analysis of set-theoretic notions to a more mathematical framework through the introduction of natural mathematical notions in both the internal algorithms of EXCHECK and its dialogue with the user.

Yale University; David R. Barstow; **Programming Knowledge for Graph Algorithms**; (MCS-7803827A01); $5,732; 6 mos.

Professor David Barstow's research is concerned with automatic construction of computer programs to solve graph problems. As an extension of this research, Mr. Safwan Bengelloun has developed a formal approach to the problem of defining new data types in terms of existing data types. This research will concentrate on the development of a programming language in which the user can inductively define maps between different data types.

Yale University; Drew McDermott; **The Representation of Spatial Information for Problem Solving and Understanding**; (MCS-8013710); $,574; 12 mos.

This research is concerned with representing spatial information for use in problem solving and other applications. It focusses on the use of "fuzzy maps" for representing regions of space and time. A fuzzy map is a map, consisting of several frames of reference, in which objects' positions are constrained by the facts assimilated so far. A generalization of this notion is to a fuzzy time tree, in which events and objects are located with respect to several different possible futures. Making this work requires new research into setting up dependencies among events in the tree. What is learned will be applied to the design of a problem solver for solving problems requiring run-time scheduling of processes occurring at various places.

Northern Illinois Univ.; Ross A. Overbeek; **Topics in Automated Theorem Proving**; (MCS-7903870A01); $29,312; 12 mos.

Over the last seven years a theorem-proving program has been developed at Northern Illinois University which has recently established answers to three open mathematics problems in Boolean algebras and semigroups. The current research will be directed towards the following goals:

(1) expansion of the class of open mathematics problems that can be addressed by the system,

(2) continuation of the work on paramodulation,

(3) examination of capabilities of other theorem-proving systems (notably, that of W. W. Bledsoe at the University of Texas, Austin),

(4) examination of a class of problems in Tarskian geometry which to date have dified solution by any theorem-proving system.

Northwestern University; Lawrence J. Henschen; **Automated Theorem Proving**; (MCS-7913252); $48,500; 12 mos.

The objective of this research is to extend the theory of automated mathematical deduction using the formal language of mathematical logic. Two major problem areas will be investigated: (1) a new non-resolution technique involving the calculation of "covering terms" for determining the remaining permissible truth value assignments to clauses at each stage of the deduction; (2) incorporation of splitting rules for higher-order logic into the unification algorithm.

University of Illinois-Urbana; Ryszard S. Michalski; **Studies in Computer Induction and Plausible Inference**; (MCS-7906614A01); $35,613; 12 mos.

Current methods of knowledge acquisition for knowledge-based expert systems require the laborious incorporation of human experts' knowledge of specific domains in a formal system, such as production rules. Professor Michalski's research in plausible inference provides an approach to automating this process of knowledge acquisition from empirical data. His approach has been validated in a series of successful experiments in automating the inference of diagnostic rules for plant pathologies. The objectives of the present project are the formulation of a comprehensive theory of induction and plausible inference based on the earlier work, and the development of computationally efficient algorithms for computer implementation of the theory.

Univ. of Maryland College Park; Jack Minker and Barry E. Jacobs; **Applications of Logic and Theorem Proving to Databases**; (MCS-7919418); $107,835; 36 mos (Joint support with the Division of Information Science & Technology - Total Grant $207,835).

The major thrust of this research is the application of automated theorem proving and mathematical logic to database investigations. Three types will be treated: (1) theorem proving by linear resolution with unrestricted selection function using trees , (2) first-order logic and databases, and (3) database logic.

Database logic is a recently developed formalism whereby existing database systems can be viewed in terms of logic. It has the prospect of providing a unifying theoretical framework for database systems.

Mass. Inst. of Technology; Gerald J. Sussman and Carl E. Hewitt; **Computer Aided Evolutionary Design for Software Engineering**; (MCS-7912179); $50,000; 12 mos (Joint support with the Software Engineering Program - Total Grant $100,000).

Large software systems are generally associated with high cost and low reliability. These problems are not due primarily to sloppy programming or poor management, but rather are symptoms of the lack of technology for aiding software engineers in the process of evolutionary design. The fundamental issues involved in constructing an interactive computer aided design tool for software engineering will be investigated. The principles developed in this research should be applicable to the construction of similar aids for other engineering disciplines. Automatic program verification techniques now available form only part of the methodology necessary to provide powerful assistance to the designers and implementers of large systems. Verification techniques are most suitable for proving the correctness of algorithms. The complexity and evolutionary nature of software systems requires a number of additional techniques.

The evolutionary nature of large systems is partially due to the fact that simplifying assumptions must be made in order to come up with an initially feasible design. Unfortunately, such "first order" designs need to be debugged when the simplifying assumptions are relaxed. This calls for design aid techniques which deal effectively with changing and incomplete specifications.

The managing of complexity is a fundamental issue in all engineering disciplines. Identified are three major techniques used in more mature engineering fields such as electrical and mechanical engineering which seem applicable to the engineering of software systems, incremental modelling, multiple and almost hierachical decomposition, and analysis by inspection.

Univ. of N. H. Durham; Eugéne C. Freuder; **Constraint Satisfaction: Relating the Structure of the Problem to the Structure of the Solution**; (MCS-8003307); $24,236; 12 mos.

Many search problems conform to the following general model: find values for a set of variables which simultaneously satisfy a collection of constraints. The eight queens problem, the graph coloring problem, the scene labeling problem, data base retrieval problems are among the many which fit this mold. Backtrack and contraint relaxation algorithms are used on these problems. Many are combinatorially explosive. Some heuristic techniques are available to improve search efficiency. More are needed. At present it is pretty much a matter of experiment or trial and error to determine when a given heuristic will be effective on a given problem. Results are required which tell us when to apply these heuristics.

Specifically, results are sought of the form: if the problem has structure A, solution method B has benefit C. In particular relationships are sought between the graph structure of constraint connections and the order in which constrained variables are chosen for instantiation. The central goal is to provide guidance in choosing a search technique appropriate to the task.

Rutgers University; L. Thorne McCarty and N. S. Sridharan; **An Experiment in Artificial Intelligence and Legal Reasoning**; (MCS-7921471A01); $101,607; 12 mos.

This project uses the methods of artificial intelligence research, within the domain of corporate tax law, to investigate the mechanization of legal reasoning and legal argumentation. A formal model of concepts in the corporate tax field will be developed and alternative implementations of the model in functioning computer programs will be investigated. The model will be validated and tested on specific stock dividend cases.

Rutgers University; Richard Statman; **Syntax and Semantics of the Typed Lambda-Calculus**; (MCS-7923199); $7,255; 12 mos.

This research is concerned with the applicability of the calculus to computer science, and in particular to automated theorem proving. The project will include: (1) analysis of the complexity of specific problems in type theory, and (2) development of model theory as a tool for solving proof-theoretic problems.

SUNY St. Univ. Stony Brook; Herbert Gelernter; **Computer-Directed Organic Synthesis Route Discovery**; (MCS-7816786A01); $72,313; 12 mos.

SYNCHEM2 is a large scale computer program which uses heuristic graph-searching techniques to discover synthesis routes for complex organic molecular structures. The initial version of this program is currently running on the NIH/DCRT 370/168 computer in Bethesda, Maryland. Available to qualified users, it has attracted considerable attention in the pharmaceutical industry.

The current research program is focused on developing advanced heuristic graph-searching and problem-solving techniques to enable the system to calculate more complex molecular structures than are feasible under the computational limitations of the present system.

Carnegie Mellon Univ.; Peter B. Andrews; **Automatic Theorem Proving in Type Theory**; (MCS-7801462A02); $47,691; 12 mos.

This research is directed toward enabling computers to construct and to check proofs of theorems of mathematics and other disciplines formalized in type theory or first order logic. An existing computer program which proves theorems of type theory will be improved, and extended to work directly with sentences which have not been reduced to clauses, and to construct proofs in natural deduction format. Matings of literal-occurrences in such sentences and proofs will be investigated, along with various other logical phenomena.

Univ. of Texas-Austin; Woodrow W. Bledsoe; **Research on Automatic Theorem Proving and Applications**; (MCS-7720701A03); $76,700; 12 mos.

This research is a continuation of previous work in automatic theorem proving and its application to program verification and mathematics. Earlier work has included the development and running of computer programs which: (1) prove theorems as part of a program verification system; (2) prove theorems in analysis, using a non-standard analysis methods; and (3) utilize data-base manipulation reudctions, and relatd concepts.

The early work included results on Presburger arithmetic, complete sets of reductions, and set variables. The present investigation continues this work emphasizing: (1) program verification; (2) further development of a "set variables" prover and a "goal tree" prover and (3) improved natural language interface with the user.

Additional applications of automatic theorem proving will be sought, such as inferential queries from large data bases.

Univ. of Texas-Austin; Frank M. Brown; **Automatic Inference in Metatheory**; (MCS-8004210); $48,000; 24 mos.

Deductive and inductive reasoning in a computationally efficient metatheory will be studied by considering several areas: the metatheory of classical logic, the metatheory of intensional logics, natural language, high level programming languages and metatheoretic concepts used in mathematical reasoning.

SPECIAL PROJECTS

DATABASE RESEARCH

Univ of Calif-Berkeley; Lawrence A. Rowe; **End-User Data Base Application Development**; (MCS-8006329); $50,000; 12 mos.

This project deals with the development of programming constructs and their implementation for interactive data base applications. Many end-user applications require sophisticated screen-oriented input-output facilities coupled with data base facilities for retrieving, storing, and manipulating variable length text values (e.g., abstracts of papers or course descriptions). Currently exixting programming environments do not support well-integrated software tools for developing applications with these requirements.

The investigators will extend the existing data base programming language, RIGEL, to support the text formatting and screen input-output facilities that are required. Benefits anticipated from this research will be a demonstration of how these facilities can be integrated with a data base and a text formatting system to provide the programming environment needed to construct end-user applications quickly, reliably, and with a high degree of data and terminal independence. In a related area, development will begin on a very high-level language (VHLL) optimizer which includes both existing query language and other VHLL optimizations to produce efficient implementations of the resulting programs.

Univ. of California, Berkeley; Alan Jay Smith; **Automatic File System Design and Optimization**; (MCS-7728429A01); $41,600; 12 mos.

The recent introduction of commercially successful mass-store computer devices with more than a trillion bits of storage, and the expected introduction of gapfiller technology for a level of storage between main memory and disk have underscored our lack of understanding of hierarchical computer file system operation. This project will study automatic file systems, with the goals of understanding their use and optimizing their operation.

The plan is to measure several large computer systems and use the data collected to characterize file system operation and to create and validate models and optimization algorithms. The research is is concentrated in three broad areas:

(1) To optimize the operation of automatic file systems;

(2) To study the design and configuration of the memory

hierarchy by using measured data; and
(3) To characterize file access patterns and user behavior so as to predict the effect of anticipated changes in computer system technology.

Univ. of California-Los Angeles; Allen Klinger; **Combining Numeric and Graphic Data**; (MCS-7816754A01); $59,448; 12 mos.

The research project will study problems related to:
(1) data structures well-suited to flexible combination of numeric and geographic data,
(2) selective merging of portions of very large databases, and
(3) programs to permit interactive indexing for computer display of map-like images, and of selected numeric indicators.

The research plan will extend current computer science research in the following areas: data structures (selection, analysis of algorithms), data base management (large pictorial arrays), and man-machine interaction (selecting areas for display). The project will concentrate on human interaction with simultaneous display of graphical and numerical data an on the development of the methodology and needed data structures to permit such use of different but related data bases.

University of Florida; Stanley Y. Su; **Conversion of Application Programs in the Data Base Management Systems Environment**; (MCS-7826761); $100,247; 24 mos.

This project has two main emphases: 1) the study of the problem of program conversion resulting from logical database changes and from the change from one DBMS to another, possibly with a different data model and data sublanguage, and 2) the investigation of good and bad programming practices which may affect the programming productivity of programmers and the maintainability and convertibility of application programs.

An application program can be decomposed into a high-level semantic representation which is independent of the data model used in the source and target DBMS. This representation is described in terms of primitive access patterns useful for the traversal of data in accordance with their semantic relationships. Transformations of the semantic representation of a program are performed to account for the changes in the original database brought about by data conversion operators. The transformed representation is then used to generate the target program for the same or a different DBMS. Language templates are used for both program analysis and synthesis.

The research based on a descriptive model of program conversion includes: 1) the semantic modeling and description of database and application programs, 2) the definition and proof of the equivalency of source and target programs, 3) the decompilation and synthesis of COBOL/DML programs, 4) the verification and improvement of application programs. 5) the optimization of target programs and 6) the implementation of a prototype system.

Purdue University; S. B. Yao; **Design, Modeling and Performance of Data Base System**; (MCS-7905539A01); $49,952; 12 mos.

The problem addressed concerns the design of appropriate system architectures and application models for the construction of large data bases within on-line information systems. The design of a data base is commonly separated into two phases: 1) the logical design, defining and combining the data requirements of many applications into a centrally controlled and maintained logical data base, with provisions for data sharing and protection, and 2) the physical design, including all the implementation details and considerations of a particular data base system.

The purpose of this research is to apply new theory regarding logical and physical data base design to the following problems.

1. Develop performance evaluation tools based on current data base structure models and simulation/analytic techniques.
2. Develop performance enhancement aids based on special algorithms and optimizaton techniques.
3. Design data base systems with built-in optimization components that otimize the storage structure and the query evaluation.
4. Develop semantic models for the design and optimization of logical data base structures of data base applications.

University of Maryland; Ben Shneiderman; **Structured Data Base Systems**; (MCS-7722509 A03); $52,323; 12 mos.

This project will investigate:

1) techniques for formal definition of data models and mapping between data models or schema levels within a model.
2) transformations between relational, network, and hierarchical database models.
3) the extension of the structural descriptions of data to include behavioral descriptions.

University of Michigan; Dennis G. Severance; **Pliable, Elastic, and Durable, Secondary Memory Frames: Their Application to Database Design**; (MCS-7826597A01); $55,359; 12 mos.

This project will develop and implement the new concept of a secondary memory record frame and investigate its effects upon current approaches to the design of large shared databases.

The research has four significant goals; (1) substantially reduce the number of fundamentally distinct database design alternatives--an analyst may therefore more easily cope with the problem of choosing among them; (2) develop fundamental alternatives which are structurally simpler than existing ones and more amenable to modelling--either simulation or analytic estimation will be more readily applied to predict the performance of proposed designs; (3) provide a framework for automated design procedures--it will be possible to provide a systems analyst with significant assistance when choosing among alternative database structures; and (4) propose a natural bridge for the transition from a disk-oriented memory environment to a staged hierarchy of device types predicted for the next decade--designs built upon frames will easily evolve.

Carnegie Mellon Univ; Steven J Fenves, Charles M Eastman, and Arthur W. Westerberg; **Data Base Methods for Design**; (MCS-7822328A01); $176,840; 12 mos.

The large integrated databases proposed in a number of engineering fields significantly change the context within which design takes place. To date we have only limited theory, precedent, and experience available to guide the design of these databases.

This project, addresses the conceptual formulation of an integrated engineering database that is capable of:

(1) supporting a variety of multidisciplinary, hierarchical, iterative design processes from early conceptual design through manufacturing, fabraicaton, operation and maintenance of engineering systems without imposing an *a priori* sequence of design operations; and

(2) performing automatically a large segment of integrity and consistency management within the database.

Specifically, it will develop a database organization which can automate three major consistency issues; detection, isolation and correction.

Vanderbilt University; Patrick C. Fischer; **An Integrated Approach To The Design Of Data Base Management Operating Systems**; (MCS-8007706 & A01); $74,920; 12 mos.

The performance, integrity, security and reliability of a data base management system (DBMS) is of prime concern to its users. Since most DBMS's are constructed as a subsystem on top of the operating system, problems of performance, integrity and security in the DBMS cannot be separated from the same problems in the operating system (OS). Little attention has been given until now to the DBMS/OS interface and its effect ot the operation of the DBMS.

The goal of this research is to construct a common DBMS/OS kernel which supports both OS and DBMS functions on an equal status. The investigators plan to use the concepts of capabilities and typed objects in the design of the kernel. The first objective is to develop a concise conceptual model of the relevant objects and processes. Subsequently, analysis and simulation techniques will be used to investigate the performance tradeoffs associated with the suggested approach.

PRIVACY & SECURITY

Stanford University; Martin E. Hellman; **Data Security**; (MCS-7916161); $13,632; 12 mos (Joint support with the Electrical & Optical Computing Program - Total Grant $54,530).

This research program is concerned with increasing the understanding of the use of cryptography in data security. Public key cryptosystems and their relationship to digital signatures are being studied along with cryptographic systems with a high level of mathematical structure. Efforts are being devoted to the certification process by which a system is tested for weaknesses prior to being designated as secure. The study is directed to general methods, such as time-memory tradeoffs, and to specific cryptographic systems, such as the Federal Data Encryption Standard.

George Washington Univ; Lance J. Hoffman; **New Models and Metrics in Computer Security**; (MCS-7724235A02); $42,658; 12 mos.

This project will refine a set-theoretical model of computer installation secrity and to improve and extend its accompanying rating system. The underlying security model will be applied to computer installations and other areas characterized by large numbers of interactions within complex systems and imprecise metrics of security effectiveness. While the underlying model will remain nearly the seam, the human interface will probably be custom-designed for each new application area. Measurements of the cost of using the system will be obtained, and an attempt will be made to develop an appropriate security rating language which most users will find intuitive.

Princeton University; Richard Lipton; **Secure Computation**; (MCS-8023805); $16,654; 12 mos.

Concepts from the fundamental computer science fields of complexity analysis and programming systems will be used to continue the exploration of problem areas in database security and protection mechanisms.

In the area of protection mechanisms, the research will concentrate: (1) more specific systems to determine their policies in the context of a graph model; (2) rule generalizations that lead to effective and efficient policies; (3) the feasibility of developing a language for policy specification; and (4) tradeoff between static and dynamic system validation.

In data base security, work will proceed on: (1) the number of inquiries necessary to compromise a database; (2) further exploring the limitations of deliberate injection of errors into a data base to assure security; and (3) studying the audit problem of determining whether a sequence of inquiries has compromised a database.

This research is collaborative with Anita K. Jones, Carnegie-Mellon University and Lawrence Snyder of Purdue University.

Rutgers University; Naftaly Minsky and Abe Lockman; **Protection of Information Systems**; (MCS-8009811); $63,357; 12 mos.

This research is a continuation current of efforts to develop a protection scheme suitable for a wide variety of large scale information systems. Starting with the previously developed Operation Control scheme, the investigators plan to augment their scheme, working towards the following broadly defined goals: a) development of analysis of techniques which can answer questions about the policy being supported by a given protection state of a system; b) optimization of the representation and enforcement of policies; c) augmenting the expressive powers of our scheme's constructs to enable the protection of the highly dynamic processes of system building and modification; d) development of a useful methodology for mapping informal statements of desired policies into formal protection constructs.

THE SOCIETAL IMPACT OF COMPUTING

Stanford University; Donald Dunn; **Economics of Computer Communication Networks**; (MCS-7802272A02); $82,458; 12 mos (Joint support with the Division of Information Science & Technology - Total Grant $166,458).

A research program in the economics of computer-communication networks and computer-based information services will be undertaken. This program would continue research carried on during the past five years under a predecessor grant. Studies will be made of the role of information in the U.S. economy, networks as information markets, and various aspects of the production and consumption of information services and products that computer netowrks make possible.

The major theme of the work under this grant will be to continue to develop policy-oriented models of the information sector of the economy. Projects on the special nature of information as a product, on information service markets, on the distribution and role of information in non-market economies and regulated markets, on the special features of international information markets, and on the structure and behavior of the information sector of the U.S. economy are proposed.

Univ. of California-Irvine; James N. Danziger and Kenneth L. Kraemer; **A Contingency Analysis of Computer Impacts in Public Organizations**; (MCS-7905521); $61,789; 12 mos.

The success or failure of computer-based systems is commonly held to be related to:

(1) the individual attributes of the users;
(2) the nature of the technology;
(3) the character of the interactions between the information services depatment and the information users in other departments;
(4) the organization's environment, including the political framework; and
(5) the size of the community.

This project will assess these factors empircally using contingency theory as the conceptual framework to structure the analysis. It will treat selected aspects of the organization's environment (size, political framework) as forces which influence its structure (organization structure, EDP structure) and also its performance (utilization, productivity, quality of work, problems). It will also examine the user-technology interface (traits of user, nature of the technology, character of user-provider interactions) as an intervening variable between environment and structure on the one hand and performance on the other. The general hypothesis is that environment specifies the strategies which are most appropriate for information sytems success. Moreover, the appropriate strategies might vary depending upon the kind of performance criteria examined.

The data for the analyses have been collected from 2176 municipal personnel ranging from top managers and department heads to clerical workers. In explaining between government variation in performance, analyses will be conducted primarily at the city level, and also at the department and role level.

The research results will be disseminated to practitioners as well as to academics in computer science, public administration/political science, and management information systems.

Univ of Calif-Irvine; Rob Kling; **Concepts and Issues in Instrumental Computer Use**; (MCS-7720831A02); $89,073; 12 mos.

Despite continuing technical advances, computer use is still costly in its demand for attention and special skills by people who try to use it to further their own work. The cost, in time and frustration, borne by instrumental users may become a substantial fraction of the cost of a system during its life cycle. These costs are poorly understood and have yet to appear in the figures cited for total system costs.

This project will:

1. Identify the major problems that arise when people use computing as a working tool;
2. Learn how the severity of these problems varies with different kinds of computer technology and different ways of organizing access to it;
3. Identify the major strategies that users have fourn to lessen the problems they confront with computer use.

The research strategy proposed for studying these issues includes:

1. Two exploratory case studies;
2. A compartive case study with includes eight work groups that use computing routinely;
3. Secondary analysis of data colledted from two national surveys of computer use in local governments.

Institute for the Future; Roy Amara and Hubert Lipinski; **Interactive Group Modeling: A New Methodology For Computer-Based Scientific Communication**; (MCS-7701424A03); $175,900; 12 mos.

The researchers will extend their experimental PLANET-2 computer conferenceing system to support interactive group modeling. They will conduct a series of experiments focusing on the use of computer based conferencing (CBC) as a modeling tool.

They willl pay particular attention to CBC as applied to:

1) Modeling among remotely dispersed participants
2) Interfacing model builders and model users
3) Documenting models
4) Validating models
5) Lowering the cost of model building.

New Jersey Institute of Technology; Starr Roxanne Hiltz; **The Impact of Computer Conferencing Systems on Scientific Research**; (MCS-7727813A01); $9,980; 06 mos.

This project is a study of the impact of computerized conferencing upon scientific research communi`ties which utilize this new computer mediated medium for communication and information exchange. It will begin with studies of scientific groups using a specific system, the Electronic Information Exchange System (EIES) developed at NJIT. The research is designed to provide:

1) Information about these systems, which will improve our understanding of their design.
2) Information about how these systems affect the nature of communication within scientific research communities.
3) Information about the impact of this new type of computer system upon the structure and development of scientific specialties.

The research will use variations of the questionnaires and research procedures developed for EIES to study other computerized conferencing systems, so that comparisons among systems may be made.

New Jersey Inst of Tech; Murray Turoff; **Computer Based Conferencing**; (MCS-7800519A02); $198,442; 12 mos.

A wide-ranging set of research issues in Computer-Based Conferencing (CBC) will be explored at the Computer Conferencing and Communications Center.

Work will concentrate on the following areas:

A. The development of software and hardware capabilities to further the state of the art in the design and engineering of CBC systems. Emphasis will be on user interface languages, messaging structures, and the incorporation of microprocessors in a conferencing network.
B. Controlled experiments on the effects of CBC on human communication. These studies will explore the impact of user interfaces and system facilities on the utility of CBC.
C. Application and evaluation experiments, laboratory and field trials. The interpretation of their results will provide guidelines fo future applications of CBC and for the future development of software tools for group communication and problem solving processes.

Carnegie Mellon University; M. Granger Morgan; **Substitution of Information Technology for Energy Technologies**; (MCS-7623693A03); $80,656; 12 mos.

The proposition that the systematic application of advanced information technology can lead to major energy savings has received rather wide, thought certainly not universal, acceptance. However, this proposition has never been tested. This project will:

1. Test the extent of the validity of the proposition that a systematic application of advanced information technology can lead to major energy savings.
2. To identify basic computer science and computer engineering research problems whose solution would promote the implementation of these systems in a context which will not at the same time impose unacceptably high social costs.

MODELING & SIMULATION

Southern Ill Res Inst; William A. Fetter; **Graphical Display for Computer Model Output**; (MCS-7719959 A02); $80,000; 12 mos.

Research will continue on techniques of graphical output for computer modeling. Specifically, work will continue on refining a graphical data base to model the human body, and a wide-angle projection technique.

Work will continue on developing and refining a graphical data base which is used to display models of the human body vai computer graphics. Such displays are useful in medical simulation, and in engineering studies of human-environment interaction. Problems of modeling three-dimensional complex surfaces effectivaely and efficiently will be explored.

Wide-angle graphic concerns the problems of projecting graphical images on spherical dome screens such as are found in planetariums. Graphical output from engineering design, architectural and urban models could be displayed with such a system. The research will concentrate on developing algorithms and testing them on a dome projection facility at the Pacific Science Center at the University of Washington.

Massachusetts Institute of Technology; Edwin Kuh; **The Reliability of Economic Models**; (MCS-7726902A04 & A05); $143,000; 12 mos (Joint support with the Measurement Methods & Data Research Program - Total Grant $290,043).

This project is to support a central networking resource for research in computer model validation. The Computer Research Center will conduct research on error and model assumptions and on time series reliability analysis, and will maintain a software facility for modeling research based on the TROLL modeling language. Other funded researchers will tie into the project over a communications network, using a common software laboratory, exchanging programs and coordinating their research over a computer conferencing network.

Research in error and model assumptions will concentrate on developing reliability procedures to test the validity of theoretical assumptions underlying the algorithms in econometric models. Time series reliability anakysis will study reliability problems with regression relations and systems of stochastic equations.

This research will provide vitally needed insight into the reliability and validity of computer-based econometric models.

An additional supplement is included to permit collaboration between the American investigator, Edwin Kuh, and two leading French scholars, Michael Deleau and Pierre Malgrange, on model reliability. It also permits the presentation of some of the results of this project at the Econometrics Society Meetings in Athens, Greece.

Washington University; Mark Franklin; **Continuous Systems Simulation on Multiprocessor Systems**; (MCS-7820731 A01); $107,526; 12 mos.

The principal goal of this project is to increase significantly the solution speed and reduce the costs associated with continous system simulation on computers. The principal vehicle for achieving this goal is the exploitation of multiple processor computer architecture, in particuarl architecture based on Very-Large-Scale-Integration Technology (VLSI).

The research will be conducted in there main areas:

(1) Algorithms, parallel integration methods and higher order numerical problems associated with simulation.

(2) Systems architecture, quantifying hardware and software design parameters and system performance metrics.

(3) Systems building and research tools development, development of a systems workbench on which new ideas of structure and algorithms can be tried.

OTHER PROJECTS, SYMPOSIA, COLLOQUIA, AND STUDIES

Society for Computer Simulation; John McLeod; **Conference and Workshop on Model Acceptance to be Held May 13-15, 1981, Cannon House Office Building in Washington, D. C.**; (MCS-8020451); $9,116; 12 mos.

The credence placed in computer models developed to assist in policy formulation and decision making, and the acceptance of recommendations based on simulation studies using such models, have not been commensurate with the amount of money spent on the models and the studies using them. One reason for this is that the development and use of models has been a highly individualized and subjective procedure. No generally accepted guidelines have been available. To generate and promulgate such guidelines a Conference and Workshop on Model Acceptance will be held in Washington, D. C., May 13-15, 1981. The objective is to examine the actual acceptance of computer modeling and simulation as aids to decision making, in the light of the potential for such use, and to prepare guidelines to increase the credibility and use of models and the recommendations stemming from studies based on their use.

A proceeding covering the first-day presentations and including guidelines designed to enhance the acceptance and implementation of recommendations derived from simulation studies will be prepared and published.

Stanford University; Donald E. Knuth; **Theoretical Basis for the Development of Document Preparation Systems**; (IST-7921977); $133,000; 24 mos (Joint support with the Division of Information Science and Technology - Total Grant $338,707).

This proposal addresses problems related to the generation, representation, and display of the textual and graphical information that constitutes a 'document'.

Five main topics are considered for research: (i) Composition of graphical information (creation of figures); (ii) Specification of the layout of a document onto two-dimensional media and optimization o such a process; (iii) Exploration of unifying models of the Document Preparation Process; (iv) Transfer of information between the user and the system; and (v) Some computer-related aspects of Document Preparation Systems.

The proposed methodology emphasizes the description of problems, methods, and results using an information model common to all such problems and independent of particular devices or computer systems. The general thrust of the research will be to find a satisfactory scientific foundation for problems that have only been addressed and/or solved for very particular applications. In this way the theoretical methods and results as well as the prototype implementations that are the expected outcome of this proposal will provide a basis for much more powerful, genral and easy-to-use Document Preparation Systems.

Massachusetts Institute of Technology; Robert Gallager; **The Dynamics of Data Network Research**; (ECS-7919880); $22,000; 12 mos (Joint support with the Electrical & Optical Computing Program - Total Grant $112,630).

The objectives of this research are a) to develop new models and conceptual approaches for studying the multi-faceted problems of the distributed control of data communication networks, b) to develop and apply new algorithmic and analytical techniques for solving the problems formulated above, c) to synthesize these solutions into a better understanding of the underlying tradeoffs that exist in the engineering of efficient, reliable networks, and d) to use data networks as an example to contribute to a better understanding of the common problems that arise in controlling large scale distributed systems. The research focuses on the nature of, and the encoding of, the inter-nodal control information (i.e., the protocols) used to accomplish transfers of data in the network. Distributed algroithms for routing and flow control, and the systematic development of building blocks for such distributed algorithms is being considered.

Massachusetts Institute of Technology; Roy Kaplow; **New Interactive Computer-Use Strategies Based on the Enhanced-Input Terminal System**; (MCS-7804755A01); $52,050; 12 mos (Joint support with the Software Engineering Program - Total Grant $102,050).

A new type of computer terminal has been developed with enhanced capabilities for user input, including: user-defined, potentially unlimited symbol set; user-defined, free-format, touch-activated keyboards; and dynamically changing, software and user-controlled keyboard presentations which follow task progression. The terminal is based on graphical display device on which any keyboard design can be displayed instantaneously. This project will extend and examine the reach of this new environment for computer interaction through a two-faceted project. First, it will establish broad, affordable and more varied access through distribution over an existing two-way cable-TV network, and second, it will explore the impact of this new user/computer/video interface through study of usage patterns and through research on new languages and language concepts which the system makes feasible.

Such interfaces may have significant impact on the use of computers by non-experts, and by persons with mental or physical disabilities.

COMPUTER SCIENCE RESEARCH EQUIPMENT

University of Arizona; David P. Dobkin; **Computer Science Research Equipment**; (MCS-8006263); $52,940; 12 mos (Joint support by Software Systems Science Program and Special Projects Program).

Research equipment will be obtained to allow research in the following areas:

a) Data Structures;
b) Concurrent processes and distributed systems;
c) Computer Command languages;
d) Semantic definition of programming languages.

University of Arizona; Jay F. Nunamaker, Mary E. S. Loomis, Frank Allen, Deborah Downs, and Benn R. Kansynski; **Computer Science Research Equipment**; (MCS-8006517); $133,809; 12 mos (Joint support by Computer Systems Design Program, Software Engineering Program, and Special Projects Program).

A digital computer system will be obtained to carry out research in the following areas:

1. Database reference behaviour;
2. Database design aids;
3. The role of directories/data dictionaries in distributed systems;
4. Kernel based architectures for data base management systems;
5. Hybrid file organization schemes;
6. Automation of applications software construction.

Kent State University; Richard S. Varga and Paul S.Wang; **Computer Science and Computer Engineering Research Equipment**; (MCS-7920412); $79,000; 12 mos (Supported by the Software Engineering Program).

A VAX computer will be purchased to conduct research on the following topics:

1. An integrated polynomial and rational function manipulation system;
2. Computer algorithms for contour integration;
3. Stability of incomplete Cholesky factorizations of matrices;

4. Symbolic series solutions of two-point boundary value problems;
5. Applications of advanced computing techniques in statistics.

University of Colorado at Boulder; H. Paul Zeiger and Lloyd D. Fosdick; **Computer Science Research Equipment**; (MCS-8006501); $176,800; 12 mos (Joint support with the Theoretical Computer Science Program, the Software Systems Science Program, and the Software Engineering Program).

A digital computer system will be acquired to perform research in the following areas:

1) Software validation;
2) Program structure;
3) Software design tools;
4) Analysis of algorithms.

University of Connecticut; Taylor L. Booth and Richard E. Cullingford; **Computer Science Research Equipment**; (MCS-8006631); $100,000; 12 mos (Supported by the Software Engineering Program).

This provides equipment for research in several projects in Computer Science and Computer Engineering. These projects involve experimental studies in the areas of software engineering and intelligent system design. A common requirement for these studies is a dedicated computer facility capable of supporting large virtual address spaces, interactive creation and management of sizeable symbolic data bases, on-line instrumentation of user and operating system functions, and various symbolic manipulation and reasoning packages.

Univ of Illinois-Urbana; B. R. Rau and Michael S. Schlansker; **Computer Science Research Equipment**; (MCS-8007049); $91,483; 12 mos (Supported by Computer Systems Design Program).

A digital computer system will be acquired for research in the following area:

1) Computer architecture and emulation;
2) Simulation based investigations of computer system design;
3) Language design for simulation;
4) Residue number architecture for fault tolerant digital filters.

Indiana University-Bloomington; Edward L. Robertson; **Computer Science Research Equipment**; (MCS-8006577); $175,000; 12 mos (Joint support by Theoretical Computer Science Program, Software Systems Science Program, Computer Systems Design Program, and Software Engineering Program).

A large mini-computer system will be acquired to support faculty and graduate research in the areas of programming languages, distributed systems, artificial intelligence, and applications of computer science theory toward solving practical problems in program specification, verification, and design.

University of Massachusetts, Amherst; Edward M. Riseman and Victor R. Lesser; **Computer Science Research Equipment**; (MCS-8007763); $119,945; 12 mos (Joint support by Software Engineering Program, and Intelligent Systems Program).

A large disk storage unit and a color graphics system will be obtained to carry out research in the following areas:

1) Models of Visuomotor Coordination;
2) Software Development Systems;
3) Segmentation and Interpretation of Natural Scenes;
4) Cooperative, Distributed Problem Solving;
5) Goal Seeking Systems.

University of Michigan; Richard A. Volz; **Computer Science Research Equipment**; (MCS-8007023); $89,400; 12 mos (Joint support by Computer Systems Design Program and the Intelligent Systems Program).

A 300 million byte disk storage system and a robot will be purchased to enable research in the following areas:

a) cellular computers and image processing;
b) robot modelling and control;
c) man-machine interaction;
d) design methodology for high performance, application directed computers.

Univ. of Minnesota; J. B. Rosen, William B. Thompson, and William R. Franta; **Computer Science Research Equipment**; (MCS-8006308); $118,000; 12 mos (Joint support with the Computer Systems Design Program, Software Engineering Program, Intelligent Systems Program, and Special Projects Program).

A digital computer will be purchased to carry out research on:

1) Analysis of time varying image interpretation;
2) Data access methods in distributed databases;
3) Performance analysis of distributed systems;
4) Empirical validation of queuing network models;
5) Numerical methods for time dependent partial differential equations and global optimization problems.

Cornell University; Juris Hartmanis; **Computer Science Research Equipment**; (MCS-8006921); $200,919; 12 mos (Joint support by Software Systems Science Program, and Software Engineering Program).

A digital computer system will be acquired to conduct research in the areas of:

1) Program Verification;
2) Specification Languages and Logics;
3) Data Types and Polymorphism:
4) Program Development Systems;
5) Distributed Computing.

University of Rochester; Jerome A. Feldman; **Acquisition of Computer Science and Computer Engineering Research Equipment**; (MCS-7916911); $100,000; 12 mos (Joint support by the Software Systems Science Program and the Intelligent Systems Program).

A medium scale computer system with virtual memory capability will be acquired to carry out research in the following areas:

1) methods for representing images and other highly constrained information;
2) computer vision;
3) languages for distributed computing;
4) methods for using the computer as a programmer's assistant in writing and debugging programs.

State Univ of New York at Buffalo; Larry D. Wittie; **Computer Science Research Equipment**; (MCS-8006925); $65,000; 12 mos (Joint support by Software Systems Science Program, and Computer Systems Design Program).

Computer and testing equipment will be obtained to expand a network of microcomputers and carry on research in the following areas:

1) Self scheduling in computer networks;
2) Concurrent and distributed processing in computer graphics and computational geometry;
3) Parallel programming languages for microcomputer networks;
4) Analysis of communications in large networks of microcomputers;
5) Uses of microprocessor networks for computerized axial tomography.

Ohio State University; Charles A. Csuri; **Computer Science Research Equipment**; (MCS-8006322); $107,400; 12 mos (Joint support by Computer Systems Design Program, and Intelligent Systems Program).

Memory and auxiliary equipment will be purchased to expand a VAX 11/780 system to conduct research in the following areas:

1) Computer imagery;
2) Animation of computer images;
3) Distributed graphics systems;
4) Dynamics and control of industrial manipulators.

Brown University; Richard B. Millward; **A Real-Time Laboratory Computer for Cognitive Science**; (BNS-7816273A01); $4,500; 6 mos (Joint support by the Intelligent Systems Program, the Memory & Cognitive Processes Program and the Linguistics Program - Total Grant $18,250).

This award is to provide supplementary funding to BNS78-16273 in order that additional core memory be purchased.

Rice University; Kenneth W. Kennedy; **Computer Science Research Equipment**; (MCS-8008887); $114,936; 12 mos (Joint support by Theoretical Computer Science Program, Software Systems Science Program, Computer Systems Design Program, and Software Engineering Program).

A medium scale digital computer system will be acquired to conduct research in the following areas:

1) Organization and management of parallel systems;
2) Optimization of languages and compilers for parallel machines;
3) Parallel algorithms;
4) Numerical methods for parallel machines.

University of Virginia; Alan P. Batson; **Computer Science Research Equipment**; (MCS-8006576); $149,000; 12 mos (Joint support by Software Systems Science Program, Computer Systems Design Program, and Intelligent Systems Program).

A VAX 11/780 computer system will be purchased to carry on research in the following areas:

a) Program behavior and memory management;
b) Three dimensional image understanding;
c) Formal semantics of programming languages;
d) Software design studies for large-scale parallel computations;
e) Distributed computer systems.

University of Wisconsin-Madison; Larry E. Travis; **Computer Science Research Equipment**; (MCS-8006499); $90,025; 12 mos (Joint support by Software Systems Science Program, Computer Systems Design Program, Software Engineering Program, and Intelligent Systems Program).

Network interface equipment, a hardware monitor and graphics terminal will be obtained to carry out research in:

a) software engineering:
b) architectures for database machines;
c) operating systems for distributed computers;
d) image analysis;
e) knowledge based systems.

EXPERIMENTAL COMPUTER SCIENCE

University of Washington; Jerre D. Noe; **A Functionally Integrated Environment for Distributed Computation**; (MCS-8004111); $819,037; 12 mos.

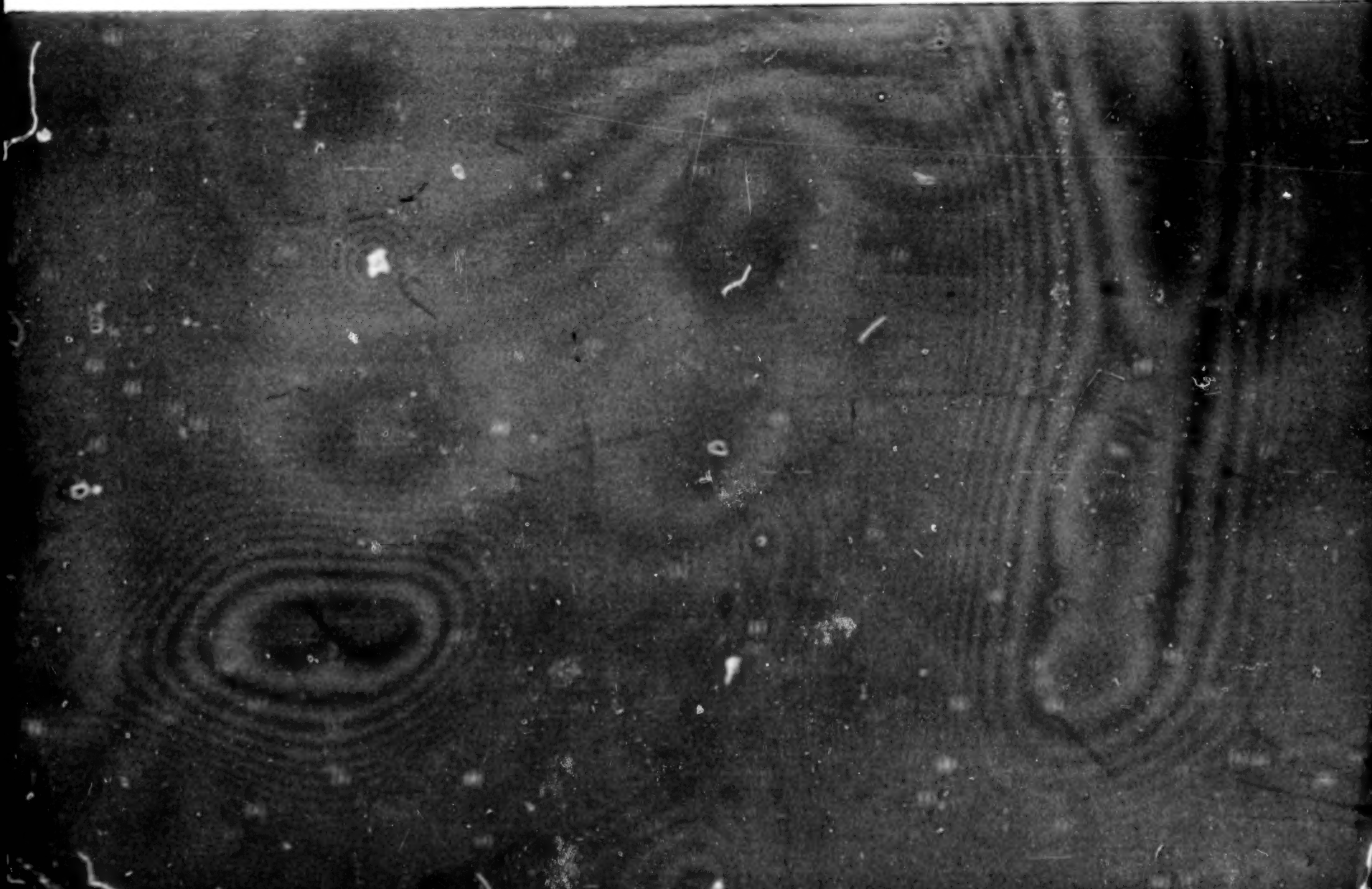
This award will aid in the establishment of a Large Scale Experimental Research (LSER) facility at the University of Washington. The investigators will design and build a powerful new kind of computing environment to facilitate communication and cooperation among researchers in the Department of Computer Science. It will be based on a "building sized" highly-parallel computer consisting of a functionally integrated collection of physically distributed personal computers cooperating through a local network. The primary focus of the research will be the development and exploration of programming methodologies, adapted to a distributed concurrent environment, which give each user access to the power and diversity of the entire system.

Univ of Wisconsin-Madison; Lawrence H. Landweber; **CSNET-A Computer Science Research Network**; (MCS-8007757); $49,809; 06 mos.

This grant provides support for a vehicle to examine alternatives for the establishment of a computer science communications network. Over the past decade, experience has been gained with the use of computer networks to facilitate research through more efficient and effective interaction among investigators. A purpose of the present project is to evaluate the network options that are presently available to the computer science community, which is poised to organize, develop and extend existing networks and networking technology.

The project will proceed in three stages. First, a workshop will be held to assess the present state of development of existing networks including ARPANET and public nets. Second, a survey of the computer science community will be conducted to understand better the potential user community and the desired services that should be provided. Last, a report will be written to recommend the most desirable courses of action.

An objective of the project is to help build a consensus in the computer science research community regarding the role that networking can play in the overall development of experimental computer science.



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